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A Study of the Feasibility of Utilizing Solid Wastes for Building Materials Phase I Summary Report

Material Systems Corp, Escondido, Calif

Prepared for

**Municipal Environmental Research Lab, Cincinnati, Ohio Solid and Hazardous
Waste Research Div**

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FOR BUILDING MATERIALS
Phase I Summary Report

by

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ABSTRACT

A comprehensive literature search was conducted. The data were reviewed and evaluated for potential matrix, reinforcement, and filler candidates. The more promising candidates were evaluated with limited laboratory studies. From these studies, two types of matrices--furfural-phenolic and inorganic--were selected for further study. Seven reinforcement candidates and five filler candidates were selected for evaluation with the two matrices. A detailed Work Plan for Phase II based on the Phase I study is also presented.

This report was submitted in fulfillment of Contract No. 68-03-2056 by Material Systems Corporation under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 1973 to June 1974, and work was completed as of June 1974.

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CONTENTS

Abstract	iii
Figures	vi
Tables	vii
Acknowledgment	viii

1. Introduction	1
2. Evaluation and Analysis	3
3. Laboratory Studies	29
4. Candidate Selections	36
5. Phase II - Test Development Work Plan	47

Appendices

A. Samples of collected data	60
B. Examples of data request	65
C. Abstracts of matrix data	69
D. Abstracts of reinforcement data	92
E. Abstracts of filler data	127
F. Letters and other information	139

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FIGURES

<u>Number</u>		<u>Page</u>
1	Stress-Strain Diagram for MSC Inorganic Matrix	15
2	Photomicrograph of "Silvacon 412"	20
3	MSC Inorganic Matrix Reinforced with Ground Waste Plastic, Wood Bark, and Wood Fiber.	34
4	MSC Inorganic Matrix Reinforced with Cotton Waste	35
5	MSC Inorganic Matrix Reinforced with Rice Hulls and Waste Plastic	35

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TABLES

<u>Number</u>		<u>Page</u>
1	Key Words for Computer Search	4
2	Rating System	6
3	Matrix Ratings	13
4	Reinforcement Ratings	17
5	Filler Ratings	26
6	Temperature - Time Cure Study	30
7	Property Comparison of Furfural & Phenols	31
8	Fly Ash Filler Evaluation	37
9	Selected Reinforcing Candidates	44
10	Selected Filler Candidates	46
11	Laboratory Tests to be Conducted	50

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ACKNOWLEDGMENT

This is to acknowledge the assistance of Albert J. Klee, Charles Rogers, and Robert E. Landreth of the Solid and Hazardous Waste Research Laboratory, National Environmental Research Center, Cincinnati, Ohio. They and their staff conducted a literature search and provided many of the data used in this study. They also provided raw material samples for evaluation.

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technical and economical feasibility, evaluate the potential for supply and qualify selected candidates. This report is a summary of Phase I.

INTRODUCTION

Material Systems Corporation and the Solid and Hazardous Waste Research Laboratory of the National Environmental Research Center at Cincinnati, Ohio have initiated a joint effort development study for the application of waste materials for residential and commercial construction. These waste materials will be evaluated as to their ability to be integrated into a composite material.

Composite materials are defined in this study as one which is constructed of a reinforcement, a filler, and a matrix. The reinforcement can be a fiber, a particle, or a sheet and its primary purpose is to transfer load through the composite. The filler can be small fibers or flakes but is most effective when it is a particle. Its purpose is to displace the matrix from areas other than the reinforcement to matrix interface and also to assist the reinforcement in transferring load. The matrix is the binder that integrates the other two together and cause the composite to perform as singular material. This integration is accomplished by chemical adhesion by the matrix to the surface of the reinforcement and the filler. Only material systems applicable to this concept will be evaluated.

This study is being accomplished in two phases. Phase I ^{is} was a collection and evaluation of waste material recovery and application research conducted to date. In addition limited laboratory studies were conducted to clarify some of the results of the literature survey. Phase II will demonstrate potential,

EVALUATION AND ANALYSIS

This phase of the study was a joint collection and evaluation of research conducted to date on waste products which could be applicable for use as reinforcements, filler, and matrices. In addition limited laboratory experiments were conducted on potential candidate materials to assist in the selection.

The data was assimilated by both computer and manual research. This was accomplished by the staff at the Solid and Hazardous Waste Research Laboratory, National Environmental Research Center, United States Environmental Protection Agency, Cincinnati, Ohio. This was augmented by some manual research by the staff at Material Systems Corporation. Key words for this search are presented in Table 1. Over 200 references and abstracts were collected for evaluation. Typical samples of this data are presented in Appendix A.

This data was first reviewed by the staff at the Solid and Hazardous Waste Research Laboratory for removal of any extraneous and non applicable material. The data was then forwarded to Material Systems Corporation for review. This review resulted in the selection of those references that appeared to have contributory data. An effort was then made by both the Solid and Hazardous Waste Research Laboratory and Material Systems Corporation to acquire the selected data. Examples of these requests are presented in Appendix B.

TABLE 1

Key Words for Computer SearchPrimary

Adhesives
Aging
Binders
Coatings
Composites
Construction
Cross-Linking
Cure (Chemical)
Destructive Distillation
Fibers
Films
Glues
Hardener
Insulation
Inorganic
Laminate
Matrix (Non-Mathematical)
Molding
Monomers
Oxides
Phosphates
Plastics
Polymers
Putrusion
Pyrolysis
Resins
Starch
Thermosetting
Thermoplastic
Weatherability

Secondary

Casein
Cellulose
Compounding
Filaments
Fillers
Finishes
Foams
Formulations
Gelatin
Glasses
Impregnate
Lignin
Prepreg
Promoter
Reinforcement
Synthetic
Zein

These requests resulted in the receipt of over 80 documents. These documents were reviewed by Material Systems Corporation and coded M for matrix data, R for reinforcement data, and F for filler data. Brief descriptions on how the more applicable documents would apply to this program are presented in Appendix C on matrices, Appendix D on reinforcements and Appendix E on fillers.

The information from these documents was reviewed and candidate materials were rated by the system presented in Table 2. The candidate materials and their resulting ratings are discussed below.

Matrix Candidates

There are a variety of candidate materials. All of these have been taken through to at least limited applications. These applications in all cases are directed towards a different material concept than that being evaluated here. However, the potential of the system has been demonstrated. The candidates evaluated are as follows:

Dialdehyde Starch-Protein

Furfurals

Cellulose

Phenols

Inorganics (Cements)

Table 3 summarizes the ratings for each of these candidates as applied to a composite material.

TABLE 2

Rating System

A. Matrix Candidates

1. Curability: Ambient temperature to 150° F	5 pts
151° F to 250° F	4 pts
251° F to 350° F	3 pts
351° F to 450° F	2 pts
451° F and up	1 pt
Noncurability	0
2. Absence of Aroma:	
No odor in precursor compound or final form	5 pts
Mild odor in precursor compound and none in final form	4 pts
3. Processability	
a. Time: Requires 2 to 10 minutes	5 pts
Requires 10 to 12 minutes	4 pts
Requires 12 to 15 minutes	3 pts
Requires 15 to 60 minutes	2 pts
Requires less than 2 minutes, more than 60 minutes	1 pt
b. Pressure: Roller, 0 to 15 psi	5 pts
16 to 25 psi	4 pts
26 to 50 psi	3 pts
51 to 100 psi	2 pts
Greater than 100 psi	1 pt
c. Temperature: Ambient to 150° F	5 pts
151° F to 250° F	4 pts
251° F to 350° F	3 pts

	351° F to 450° F	2 pts
	450° F and up	1 pt
4. Physical Form:	Liquid	5 pts
	Soluble Solid	4 pts
	Insoluble Solid but fusible below 350°F	3 pts
	Insoluble Solid but fusible below 500°F	1 pt
	Inprocessable by our standards	0
5. Toxicity:	Nontoxic	5 pts
	Noxious	3 pts
	Toxic	0
6. Decomposability:	Undecomposed to 600°F	5 pts
	Undecomposed to 550°F	4 pts
	Undecomposed to 500°F	3 pts
	Undecomposed to 400°F	2 pts
	Undecomposed below 400°F	1 pt
7. Color:	Absence of Color	3 pts
	Light Color	2 pts
	Dark Color	1 pt
	Black	0
8. Availability:	Available in Useable State	10 pts
	Useable but in Short Supply	4 pts
	Raw Mtr'l Broadly Available, Collectable, Process Known	8 pts
	Raw Matr'l Broadly Available, Collectable, Process to be dev'p	7 pts

Raw Mat'l Broadly Available, Collection Problems, Process Known	6 pts
Raw Mat'l Broadly Available, Collection Problems, to be developed	5 pts
Raw Mat'l Availability Localized, Collectable, Process Known	3 pts
Raw Mat'l Availability Localized, Collectable, Process to be Dev'p.	2 pts
Raw Mat'l Availability Localized, Collection Problems, Process Known	1 pt
Raw Mat'l Availability Localized, Collection Problems, to be Dev'p.	0

B. Reinforcement Candidates

1. Mechanical Properties

a. Tensile Strength: 100 psi and greater	5 pts
50 psi to 99 psi	4 pts
Less than 50 psi	1 pt
b. Modulus: 2,000,000 psi and greater	5 pts
1,000,000 psi to 1,999,999 psi	4 pts
500,000 psi to 999,999 psi	3 pts
Less than 500,000 psi	1 pt

2. Surface to Volume Ratio:

High	5 pts
Medium	3 pts
Low	1 pt

3. Length to Width Ratio:

High	5 pts
Medium	4 pts
Low	2 pts

4. Absence of Aroma:

None	5 pts
Mild	2 pts
Strong	1 pt
Stench	0

5. Availability

Available in Useable State	10 pts
Useable but in Short Supply	4 pts
Raw Mat'l Broadly Available, Collectable, Process Known	8 pts
Raw Mat'l Broadly Available, Collectable, Process to be Dev'p.	7 pts
Raw Mat'l Broadly Available, Collection Problems, Process Known	6 pts
Raw Mat'l Broadly Available, Collection Problems, to be Dev'p.	5 pts
Raw Mat'l Availability Localized, Collectable, Process Known	3 pts
Raw Mat'l Availability Localized Collectable, Process to be Dev'p.	2 pts
Raw Mat'l Availability Localized Collection Problems, Process Known	1 pt
Raw Mat'l Availability Localized Collection Problems, Process to be Dev'p.	0

C. Filler Candidates

1. Reactive to Matrix Material (In Destructive Sense)

Inert	5 pts
Very Slow (Requires at least 20 yrs)	4 pts
Slow (Requires at least 15 years)	3 pts

	Medium (Requires at least 10 years)	2 pts
	Rapid (Requires at least 5 years)	1 pt
2.	Decomposability	
	Undecomposed to above 2000°F	5 pts
	Undecomposed below 2000°F	4 pts
	Undecomposed below 1500°F	3 pts
	Undecomposed below 1000°F	2 pts
	Undecomposed below 750°F	1 pt
3.	Grindability	
	300 mesh or better	5 pts
	200 to 300 mesh	4 pts
	100 to 300 mesh	4 pts
	50 to 100 mesh	2 pts
	less than 50 mesh	1 pt
4.	Density	
	Point value = 5 Specific Gravity	
5.	Absence of Aroma	
	None	5 pts
	Mild	2 pts
	Strong	1 pt
	Stench	0
6.	Availability	
	Available in Useable State	10 pts
	Useable but in Short Supply	4 pts
	Raw Mat'l Broadly Available, Collectable, Process Known	8 pts

Raw Mat'l Broadly Available, Collectable, Process to be Dev'p.	7 pts
Raw Mat'l Broadly Available, Collection Problems, Process Known	6 pts
Raw Mat'l Broadly Available, Collection Problems, to be Dev'p.	5 pts
Raw Mat'l Availability Localized, Collectable, Process Known	3 pts
Raw Mat'l Availability Localized, Collectable, Process to be Dev'p.	2 pts
Raw Mat'l Availability Localized, Collection Problems, Process Known	1 pt
Raw Mat'l Availability Localized, Collection Problems, to be Dev'p.	0

The dialdehyde starches are derived from starch-producing vegetation such as corn and are reactive with protein type materials such as animal blood. The source of supply for the raw material is plentiful. Considerable exploration has been made with it for glue applications for bonding plywood panels. The material requires pressure and time for cure which limits it to a batch type process. The interfacial adherence to reinforcements are unknown as is the reaction as a binder rather than an adhesive. The flame resistance for building structures would not be as good as other candidates. The ability of the material to weather as an exposed matrix would also be questionable.

Furfural and furfuryl alcohol based resins are in use and have been utilized as molding compounds and matrices for reinforced composites. Quaker Oats Co. has limited production on (Quacor) a furfuryl alcohol based resin where the furfural is derived from oat hulls. Furfural is unique in that it can be derived from a wide variety of sources such as manure, oat hulls, rice hulls, corn cobs, bagasse (sugar cane), all types of cereal straws, bark and wood chips. The resin cures rapidly with minimal pressure which permits continuous processing. It is also non-flammable and generates very little smoke. The weathering would appear to be good also. The mechanical properties are equivalent to or superior to polyester laminating resins.

TABLE 3
MATRIX RATINGS

MATRIX	Curability	Absence of Aroma	Processability			Physical Form	Toxicity	Decomposability	Color	Availability	Score	COMMENTS
			Time	Pressure	Temperature							
Dialdehyde/Protein Starches	5	5	1	1	5	3	5	1	1	8	35	M-001, M-007
Furfurals (Manure)	5	4	5	5	5	5	5	5	0	6	45	M-002
Furfurals (Rice Hulls) (Bagasse)	5	4	5	5	5	5	5	5	0	8	47	M-004, M-008 M-009
Inorganics (Cement)	5	5	1	5	5	3	5	5	2	10	46	M-003
Cellulose (Reactants)	3	4	5	2	3	4	5	1	2	6	35	M-005
Phenols	3	4	5	1	3	5	5	5	1	6	38	M-006
Lignin	3	4	5	2	3	5	5	3	1	7	38	M-009

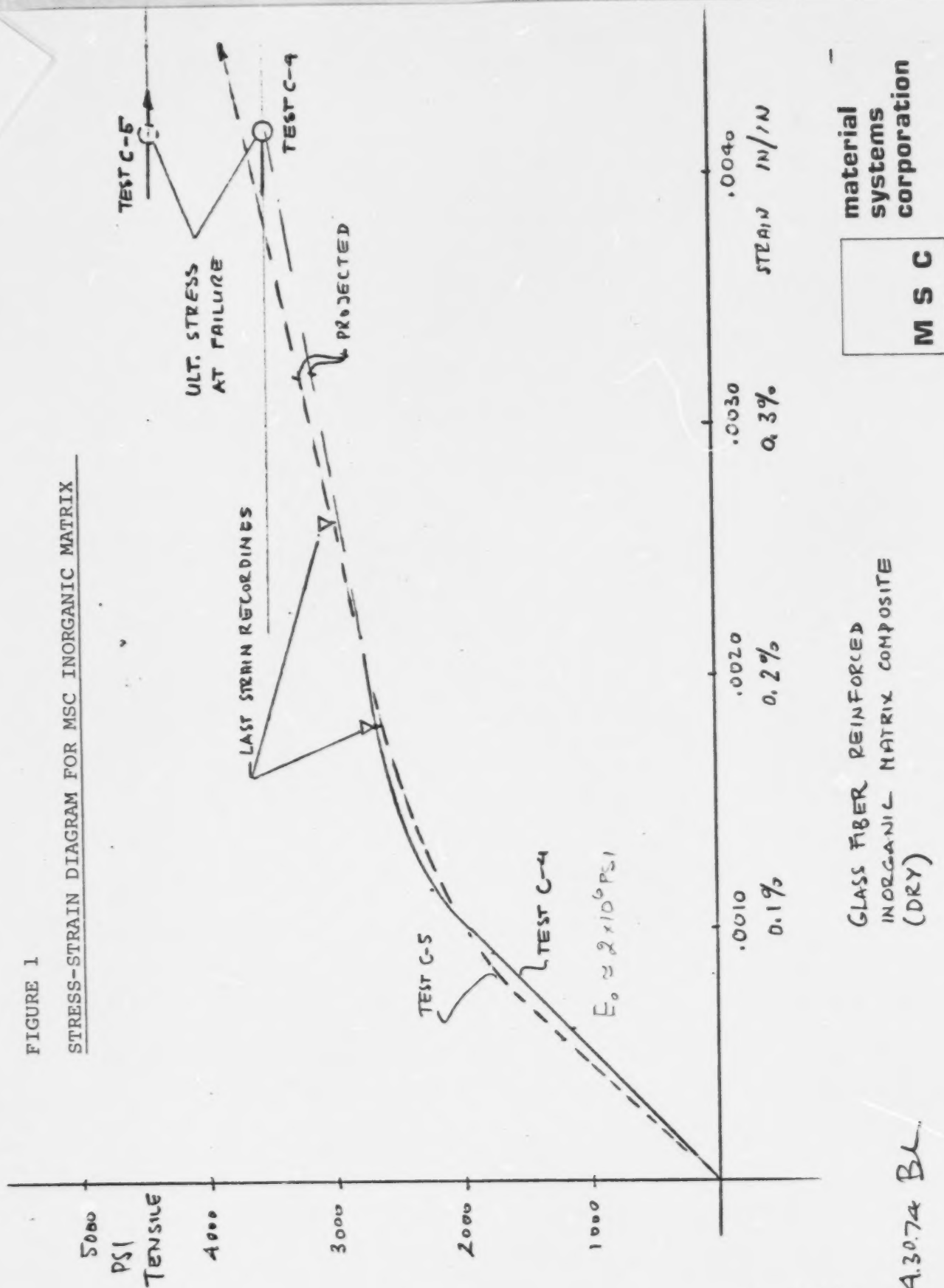
Cellulose can be reacted in a variety of ways to create a binder. The material can be derived from wood waste, cereal straw and manure. It has been evaluated experimentally to produce particle board. The mechanical properties appear to be marginal for primary type structures. The system requires heat, pressure, and time for cure which limits it to a batch process. It would not be very fire resistant and would generate smoke. The evaluation of its use in particle board would indicate poor weathering ability.

Phenols have been a basis for a variety of resins for a number of years. The phenols are best derived from wood waste. The resin requires heat and pressure for cure but very little time. These factors can be adjusted if combined with furfurals. As it exists it would be limited to a batch process. It should perform well as a flame resistant material. Mechanical properties are good but the system will require modification for weathering.

Lignin sulfonic acids are derived from the residues left after the kraft and bi sulfite treating for wood pulp. There are large quantities of these materials now available and unused. The lignin is another source for phenolic resins and can be reacted with furfurals or formaldehyde.

Inorganic resins are generally of the cement variety. Nearly all of the referenced experimental work to date has used a refractory or fired type system. Material Systems Corporation has developed inorganic resin that is cured at room temperature and displays an elastic type stress-strain diagram. (See Figure 1) This material is lightweight

FIGURE 1
STRESS-STRAIN DIAGRAM FOR MSC INORGANIC MATRIX



(0.045 lb/in³), has excellent mechanical properties, is fire resistant and does not generate smoke. The material is formulated from sea water derived chemicals. Although it is not a waste product, it does not expend natural resources.

REINFORCEMENT CANDIDATES

Reinforcements can be fibers, sheet, or particles. The candidates reviewed by category are as follows:

<u>Fiber Reinforcement</u>	-	Carbonized Lignin
	-	Bagasse
	-	Wheat Straw (Cereal Straw)
	-	Bark
	-	Kenaf
	-	Bamboo
	-	Wood Chips
	-	Cotton Waste
	-	Glass Roving
<u>Sheet Reinforcement</u>	-	Paper
<u>Particle Reinforcement</u>	-	Sewage Sludge
	-	Sawdust
	-	Rice Hulls
	-	Plastic Scrap
	-	Waste Glass

Table 4 summarizes the ratings for each of the above as applied to a composite material.

Carbonized Lignin is in an extremely preliminary research state. If it would be possible to produce high strength-high modulus graphite fibers, a major market would be available

Table 4

REINFORCEMENT RATINGS

REINFORCEMENT	Tensile Strength	Modulus	Surface/Volume	Length/Width	Absence of Atom	Availability	Score	References
Carbonized Lignin	5	5	5	5	2	0	22	R-002
Paper	5	4	5	5	5	4	28	R-003, R-023, R-024, R-025, R-026
Sewage Sludge	1	3	3	2	1	7	17	R-003, R-004
Sawdust	1	4	1	1	5	10	22	R-001, R-003
Bagasse	4	3	3	3	2	8	23	R-003, R-009
Wheat Straw	4	3	5	5	2	6	25	R-003, R-005, R-015
Rice Hulls	1	4	3	4	5	8	25	R-004A, R-012
Bark	4	4	3	4	5	8	28	R-001, R-006, R-007, R-008 R-016, R-017, R-020, R-021
Plastic Scrap	4	3	5	5	5	6	28	R-010, R-015
Kenaf	4	3	5	5	2	4	23	R-011, R-027, R-028
Bamboo	1	5	3	4	5	3	21	R-013, R-014
Wood Chips	4	3	1	2	2	8	20	R-001, R-016, R-017, R-018, R-019
Waste Glass	4	5	1	1	5	6	22	R-022, R-023, R-024, R-025, R-026
Cotton Waste	4	4	3	4	5	3	23	Supplied by Solid & Hazardous Waste Research Lab.
Glass Roving	5	5	5	5	5	10	35	Not a waste-Available from a plentiful source

in the high rise building and even in the aerospace business. However, this development work is too preliminary to be considered for use in this program.

Bagasse is the pulp remaining from the processed sugar cane. The fibers have good mechanical properties and process well with most resins. The fibers must be processed to insure the removal of all sugar or the resulting material could be attacked by insects. The availability of the material is limited in the United States and highly localized. The fibers will support combustion if exposed.

Wheat Straw (Cereal Straw) is the waste from the cereal harvest. These straws are relatively stiff and fragile. The surfaces have a wax or oil type film which creates difficulty in developing a surface bond. The material is plentiful but would create a collection problem. The potential mechanical properties are good but the fragile characteristics of the straw structure creates processing problems that prevent achievement of the properties. The material will support combustion if exposed to flame and will also be attacked by insects and fungus if not protected.

Bark is a waste from the lumber industry. It is available in a number of forms. Most of the outer bark materials are of large particles and are poor reinforcements. The inner materials have short discrete fibers and can be used to develop adequate mechanical properties. The fibers

will support combustion and if not protected will be attacked by insects and fungus. The material is available in large quantities and is being refined into useable forms. One such product is Weyerhaeuser's "Silvacon 412" (Figure 2). These fibers have excellent geometric ratios and can be used as the primary reinforcement or in combinations with other reinforcements. There are other such products becoming available as the need is defined.

Kenaf is known as a cordage crop or a substitute for jute. It is grown in Central America and Southeast Asia. It may grow 8 to 20 feet tall and does produce a highly adaptable fiber for reinforcements. Some efforts have been made to introduce kenaf in this country by the Department of Agriculture. Efforts (see Appendix F) have been made to acquire samples of kenaf for evaluation. However, there appears to be a world wide shortage of the fiber which obviously does not make it a waste product. Like other organic fibers, kenaf will support combustion and can be attacked by insects or fungus if exposed.

Bamboo fibers have demonstrated acceptable mechanical properties. Experiments by the U.S. Army Corp of Engineers show it to be a potential reinforcement for concrete. The cane is difficult to fiberize. This results in large "clumps" of fiber or pith which makes it difficult to utilize in the usual approach to composite material design. The load

FIGURE 2

Photo micrograph of "Silvacon 412"



paths become concentrated and result in premature failures of the composite. Bamboo, like all organic fibers, will support combustion and will deteriorate by insect and fungus attack if exposed. The fibers in some cases have film surfaces such as straw which reduces the interface bond strength. The supply is localized and limited within the United States.

Wood Chips are a waste product of the lumber industry. The chips, although composed of fibers, are not generally fiberized. Fiberizing is also difficult and results in short large diameter groups of reinforcements creating internal stress problems for composite materials similar to that of bamboo. These materials are being used to produce low strength particle board on an economically acceptable basis. In general the supply of wood chips have an already defined market and can be described as a recovered waste. The chips are effected by fire, insects and fungus if exposed.

Cotton Waste is the hulls, leaves, stems and some seeds that remain after the gin process. The material is available in large quantities in the South and Southwest sections of this country. The waste is a conglomeration of fiber sizes and particles. The mechanical properties are marginal. However, the composite can be designed to accommodate the limitations of the material. The material can be effected by fire, insects, fungus and moisture if exposed. Its availability and the size of the waste problem it generates makes it an interesting candidate for this program.

Glass Roving is a product produced from widely available materials. It is not a waste. However, it is readily available and provides a reinforcement of exceptional properties at an acceptable economical value. As an inorganic it resists fire, insects, fungus, and moisture very well. It should be considered a candidate for use with the waste matrices and/or filler where higher performance materials are required.

Paper wastes provide an excellent source for reinforcement. Although primarily available in sheet form, the material can be fiberized. There are multiple sources for providing paper waste. However, at this time waste paper can be reprocessed into new paper and a variety of other products to such an extent that in some locales a shortage exists. Waste paper provides reinforcement with excellent mechanical and physical properties. In many cases the mechanical properties of the composite is comparable to that developed by glass roving. The fineness of the fiber permits such a degree of compatibility with a matrix that protection against fire and environment is possible.

Sewage Sludge is available from municipal sanitation sources. The reinforcement is primarily particularized in form with a few fibers. The mechanical properties developed by such a reinforcement is low. The process for refining and productizing such a reinforcing material is yet to be developed. Bricks have been made on an experimental basis

from the material. The use of this material would require a major joint effort program with a large municipality. The economics could be justified only by the cost of waste removal.

Sawdust is a particularized waste from the lumber industry. It is being used on an economically feasible basis for a variety of products ranging from fuel to low strength particle board. When used in a composite a very dense product results. The particle size restricts mechanical properties and the large surface area requires a high matrix content to insure an adequate composite. This characteristic also improves protection from fire and environment. The existing application use of this material in other products, and its limitations makes it a questionable candidate for this program.

Rice Hulls are waste from rice harvesting. The ash of the hulls have 94.5% silica content which results in good mechanical and physical properties. The hulls have some mechanical disadvantage because of their particularized shape. The high silica content of the hull permits fire and environment protection to be accomplished with a minimal effort. Collection of the hulls can be a problem but the supply is immense particularly in California and the Gulf Coast. Bricks and concrete have been made from rice hulls. A house was constructed of cement-rice hull blocks in Rayne, Louisiana in 1923 and is in excellent condition to date.

Plastic Scrap is derived from both municipal and industrial waste. The material can be shredded but is usually available as particles. Although the basic material generally has acceptable mechanical properties, its size and shape creates some difficulty in the design of the composite similar to that of bamboo and wood chips. The primary supply source at this time would be industrial as few municipalities have the facilities for sorting their refuse. This reinforcement would be considered for specialty applications.

Waste Glass is also derived from municipal and industrial waste. The material is crushed and is in a particle form. The basic material has good mechanical properties. Its shape and size create composite design problems similar to that of plastic scrap. The material has been used experimentally to reinforce bricks and concrete. It is also recyclable into new glass. The economic potentials for the product in other applications in combination with its limitations for composites reduces its appeal for this program.

FILLER CANDIDATES

Fillers are primarily fine particles. In specific cases fillers can be very fine fibers. The filler provides a secondary reinforcing role as well as displacing matrix. The candidates reviewed are as follows:

Ash

Crushed Glass

Phosphate Slimes

Silicate Waste

Shredded Refuse
Waste Plastic
Wood Bark
Rice Hulls
Taconite
Red Mud
Coal Waste
Foundry Ash
Sawdust

Table 5 summarizes the ratings for each of the above as applied to a composite material.

Ash is an industrial waste resulting primarily from the burning of coal. It is also generated by other processes such as municipal incinerators, metal refining, etc. Fly ash is produced and readily available throughout the United States with the exception of the West Coast and the Texas-Louisiana area. It is fine, inert and performs well in a composite. The material will not support combustion.

Crushed Glass is derived from industrial and municipal waste. It has recyclable value and therefore is economically more valuable than other waste products. The primary supply source at this time would be industrial as very few municipalities have the facilities for sorting their refuse. The glass would in all probability have to be crushed by the user. The material will not support combustion.

Phosphate Slimes are a waste product from phosphate mining and are limited to Florida. The particles recoverable from the slime are useable as filler. Experimental studies have been made with them in brick production. The slimes have a high moisture content that must be removed before they are useable. The economics of this process makes the slimes as a filler source non competitive with other fillers.

Table 5

FILLER RATINGS

FILLER	Reactive to Matrix Mat'l (Dest. Sense)	Decomposability	Grindability	Density	Absence of Aroma	Availability	Score	Reference
Ash	5	5	5	3	5	8	31	F-001, F-009, F-021
Crushed Glass	5	4	5	3	5	5	27	F-002, F-005, F-006, F-007, F-008, F-010, F-014, F-015
Phosphate Slimes	3	4	5	4	2	2	20	F-003, F-018, F-022
Silicate Waste	5	4	5	3	2	2	21	F-004
Shredded Refuse	2	3	3	4	2	7	21	F-005, F-015, F-023
Waste Plastic	3	1	5	4	5	1	19	F-006, F-011
Wood Bark	4	1	4	4	2	8	23	F-012
Rice Hulls	5	3	3	5	5	6	27	F-013
Taconite	4	3	5	3	5	3	23	F-016
Red Mud (Alum. ore)	4	3	5	3	2	2	19	F-017
Coal Waste (Recover Alumina)	5	5	5	3	5	2	25	F-019
Foundry Ash	5	5	5	3	5	2	25	F-020
Sawdust	3	2	5	5	5	4	24	

Silicate Waste from paper processing is applicable as a filler. The source is very local with the processing technique yet to be developed.

Shredded Refuse is adaptable as a filler material. The availability is limited because few municipalities have sorting and shredding facilities. The organic characteristics of some of the refuse would possibly react with many of the matrices and may not age well over a period of years. The variety of particles shapes and sizes would also create a problem.

Waste Plastic is derived from both municipal and industrial waste. The difference between waste plastic for filler and plastic scrap for reinforcement is the particle size. Also, the mechanical property requirements are much less demanding. Surface and material compatibility with the matrix is much more important. Because of the greater surface area, flammability would be of greater concern when used as a filler.

Wood Bark is a waste product from the lumber industry. The fine particularized material which is unsatisfactory as a reinforcement is an advantage as a filler. As in waste plastics, the large surface area developed by these particles could make flammability a problem. The density of the material could make uniform distribution through the more dense matrix a problem. The material is widely available.

Rice Hulls are waste from rice harvesting. The size may

require that they be crushed for use in a true filler application. The hulls as is develop a good syntactic foam additive. The high silica content makes rice hulls a good filler. Although not completely inert, reaction with most matrix materials is not probable. Only minimal if any protection will be required from combustion and environment. The material is widely available.

Taconite is a waste product from iron ore processing. Its availability is highly localized. Experimental bricks and concrete have been made from it. It would make a good filler as it can be processed very fine, is inert to most matrices and will not support combustion.

Red Mud is a waste from aluminum processing. The material is localized in areas of Texas, Arkansas, Alabama and Louisiana. Much less of this material is available than that of taconite or phosphorous slimes. The particles when processed should make fine fillers. Concrete and bricks have been made from it on an experimental basis. The material is fine, inert to most matrices, and will not support combustion.

Coal Waste has a potential for producing alumina which is an excellent filler. Alumina fillers have been used by Material Systems for certain of their fire rated products for nearly six years. The process is experimental and offers future potential.

Foundry Ash and dusts from arc furnaces and sand reclaimers

have been used experimentally as fillers in epoxy resins. The supply will be localized with small out puts when compared to other candidates. The fly ash discussion will apply to foundry ash also.

Sawdust is a waste product of the lumber industry. The discussion on sawdust as a reinforcement applies here also with the exception that the fine particles are an advantage. The large surface area of this organic material could make flammability a problem. Uniform distribution through the composites could be a problem because of its density.

LABORATORY STUDIES

The preceding literature study provided insufficient information to make a selection for Phase II - Test and Development. It was therefore decided to conduct limited laboratory studies to verify some of the preliminary conclusions. These studies involved matrix, reinforcement and filler.

Matrix Studies the survey on matrices indicated that furfurals, inorganics, and phenols offer the greatest potential. Evaluation on the potential of furfurals was conducted by using a commercially available material from Quaker Oats Co. (Quacor). Although this matrix is not necessarily the product desired, it does provide an insight as to the potential of furfural systems.

TABLE 6

Temperature - Time Cure Study

<u>Initial Oven Setting</u>	<u>Final Oven Setting</u>	<u>Rate of Rise</u>	<u>Cure Time</u>
120°F	270°F	3°/min	60 min
120°F	270°F	6°/min	30 min
120°F	270°F	10°/min	18 min
150°F	270°F	9.3°/min	13 min
150°F	325°F	6°/min	29 min

TABLE 7

Property Comparisons of Furfural and Phenol

<u>Matrix</u>	<u>Smoke Density</u>	<u>Panel Thick</u>	<u>Tensile Strength</u>	<u>Flame Spread</u>
Furfural	0	.039 inches	5544 psi	17
Phenol	0	.039 inches	5931 psi	19

The first series of tests were conducted to determine the potential adaptability of a furfural system to a continuous production process. The Quacor system is capable of cure with zero pressure and is flexible regarding time and temperature. Table 6 summarizes this study. This is functional on a typical continuous processing line.

Another important aspect of a matrix is its ability to cure with a filler. Since furfuryl alcohol systems are acid cured, care must be taken to select a filler that does not neutralize the catalyst. The degree of this requirement on furfuraldehydes are yet to be determined. Laboratory tests indicated certain acid clays and alumina are adaptable as fillers. This will require further study in Phase II.

Tests were also conducted with a phenol resorcinol to determine its adaptability to a continuous process. Zero pressure cures were accomplished at 350°F within 20 minutes.

A comparison of furfural and phenol systems is presented in Table 7. Both perform well under flammability conditions.

Studies with the MSC inorganic matrix were conducted primarily to determine its adaptability to various reinforcements and filler. The basic material with no filler and reinforced with glass roving develops tensile strength in a range of 3500 to 7000 psi depending on the percentage of glass roving utilized. A typical stress-strain diagram is presented in Figure 1.

Reinforcement Studies

Studies conducted by MSC prior to this program indicate

that structural quality building panels can be constructed from polyester resin reinforced with sisal, jute, and waste-paper. The additional studies conducted in this Phase I activity were for the purpose of evaluating some of the other potential reinforcement candidates. Since all of these are organic, the studies were conducted with the MSC inorganic matrix to develop a fire-rated product.

The studies were limited to compatibility analysis such as wetting, curing and processing parameters. The materials evaluated were rice hulls, wood bark, wood fibers, cotton waste, waste plastic and henequen (sisal) waste. Figure 3 shows a variety of materials. The upper right hand specimen is reinforced with ground waste plastic, the upper left hand specimen is reinforced with ground waste plastic, wood bark and wood fibers and the lower specimen is reinforced with ground waste plastic. Figure 4 shows a specimen reinforced with cotton waste. Figure 5 shows a specimen on the right reinforced with waste plastic and a specimen on the left hand reinforced with rice hulls.

Composites were also made with furfural reinforced with rice hulls. The two materials are compatible but the strength of the material would appear to be low although not tested.

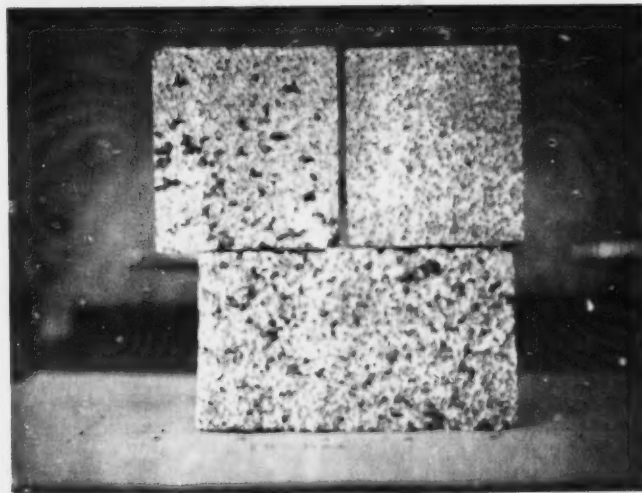
The results of these studies would indicate that most of the reinforcements in Table 4 are useable. Their selection will depend primarily on the economics and their application.

Filler Studies

Material Systems Corporation has been using calcium

FIGURE 3

MSC Inorganic Matrix Reinforced with Ground Waste Plastic,
Wood Bark and Wood Fibers



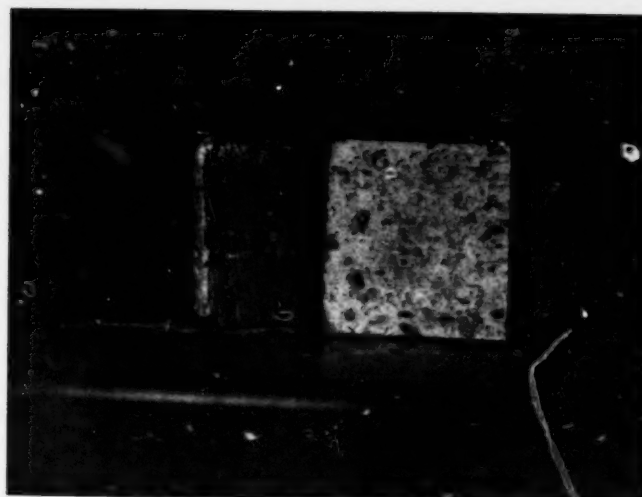


Figure 4

MSC Inorganic Matrix Reinforced With Cotton Waste

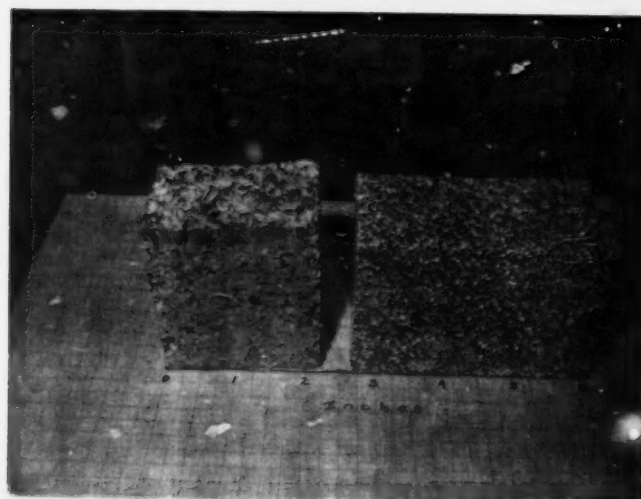


Figure 5

MSC Inorganic Matrix Reinforced With Rice Hulls & Waste Plastic

carbonate and alumina as fillers in production of polyester glass reinforced laminates for over six years. These are relatively inexpensive materials. The only reason to consider other fillers would be for different matrices such as furfural or the inorganic systems or if a waste product requires disposal.

Fly ash was selected as one system to be considered. Fly ash filled panels with polyester and glass and inorganic and glass were evaluated. The results are summarized in Table 8 and compared with standard products. As can be seen fly ash performs quite well.

The studies previously described for reinforcements apply when waste plastic, wood bark, and rice hulls are considered for fillers. The difference is particle size and their respective mechanical role in the composite.

In general ash, waste plastic, wood bark, and rice hulls would be considered as prime candidates. Crushed glass, shredded refuse, taconite, and red mud would be of secondary interest.

CANDIDATE SELECTION

Upon completion of the evaluation, analysis, and laboratory studies, sufficient information became available to permit selection of candidates for Phase II- Test and Development. The selection of these candidates for each of the three categories - matrix, reinforcement, and filler are discussed below.

TABLE 8
FLY ASH FILLER EVALUATION

<u>Composite</u>	<u>Tensile Strg, PSI</u>
Polyester/Fly Ash/Glass Fibers	8,399
Polyester/Calcium Carbonate/Glass Fiber	7,538
Inorganic/Fly Ash/Glass Fibers	3,490
Inorganic/Glass Fibers	3,650

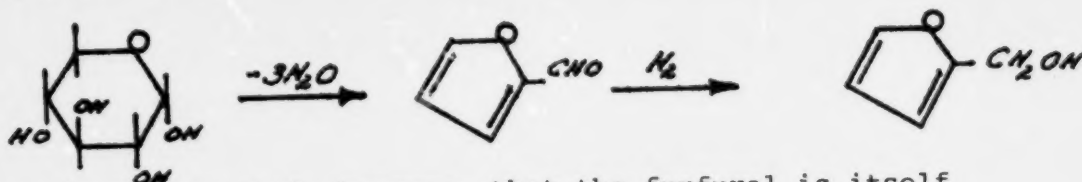
Matrix Candidates

From the studies conducted, it is obvious that the furfural, phenols, and inorganic matrices offer the most potential and are in a sufficient level of development to permit their application to this program. It is important that both an organic and an inorganic matrix be developed for housing construction. The organic will offer versatility in processing and the inorganic will provide an unusually high fire rating.

One of the most versatile, structurally strong resins commercially available is the phenolic family based on the condensation polymerization of a phenol with an aldehyde. The most common resin is based on phenol and formaldehyde; literally thousands of variations can be made from these two reactants. One possible variation of the phenolic family is to replace formaldehyde with different aldehydes. By and large this route has not been pursued vigorously because of economics; these aldehydes are all more expensive than formaldehyde or processing of the resin is more difficult because, for example, of decreased solubility in low boiling solvents such as iso propanol.

In light of our current interest to utilize waste materials, phenolic resins based on furfural appear to be particularly attractive. Resins based on the furane ring system have excellent non-flammability and very low smoke formation. The Quaker Oats Co. sells resins based on furfuryl alcohol which

have the above attributes. Furfuryl alcohol is made by hydrolysis and dehydration of pentoses in rice-hulls, corn cobs, oat hulls, manure, and other sources to afford furfural which is then hydrogenated.



It should be noted, however, that the furfural is itself highly reactive and is known to condense with phenols to give resinous products.

Material Systems Corporation proposes to combine this available knowledge on furfural-phenol reactions with work done in this country and abroad on utilization of wood wastes containing phenolic compounds. It is MSC's intent to provide a useful construction material which is based on furfural-phenol resins obtained from waste materials without the cost-increasing steps of isolating the reactants. The use of furfural generated and used in situ also represents a cost saving by elimination of the catalytic hydrogenation to furfuryl alcohol and the need to add presynthesized aldehyde to the phenol containing wood waste. Although furfuryl alcohol resins are inexpensive (about \$0.50/lb) this proposed route would drastically reduce costs because: (1) use of waste materials and (2) in essence there is no materials cost for the monomers.

In Organic Synthesis Vol I p. 250, R. Adams and V.

Voophees set forth the isolation of 180-220 g of furfural by reacting 1500 g of corn cobs with 5 liters 10% sulfuric acid and 2 kg sodium chloride. This is a substantial yield. Apparently the sodium chloride is added to salt-out the furfural, to facilitate isolation by extraction. As the process is visualized at this time, it would be desirable to omit the salt, to allow the furfural to remain in solution and to add the phenol(s), containing wood waste material or lignins from wood pulp waste for the reaction to form furfural-phenol resins. By finely dividing the rice hulls, corn cobs, or other source of pentose it may be possible to allow these fibrals to remain in the fural reaction to act as additional filler. In any event, once the reaction is conducted, the resin or matrix so formed will be present in the rice hulls and/or wood waste materials and after isolation these can be formed and heated to finish the condensation and provide a product with potential for use in the construction industry. It is reasonable to anticipate that the furfural containing binder may afford improved resistance to flammability and decrease smoke formation. The experimental details will be developed in Phase II. This is discussed in more detail in the Phase II Work Plan.

Investigations conducted by MSC on the inorganic matrix have demonstrated definite potential for a variety of waste materials. Of particular interest are cotton-waste, shredded paper, wood-bark fibers, sisal-waste, ground styrofoam scrap,

rice hulls and electric hopper fly ash. Those materials which are highly absorptive e.g. bark fibers and sisal waste lead to high density compositions because of absorption of the matrix; this can be overcome either by foaming or preparation as a syntactic foam. Most of the above waste materials show possible use as non-flammable wood substitutes. Preliminary studies indicate excellent nailability, sawability and screw retention and at a materials cost less than present prices for wooden 2" x 4" stock. Compositions using rice hulls show excellent heat insulation. After 2 hours exposure to propane air torch impinging perpendicular to the face of a 1" thick sample, heat penetration was insufficient to char a piece of masking tape on the rear face of the sample.

The inorganic matrix is produced from constituents removed from sea water. The large availability of the basic raw materials and the ability for the matrix to react compatibility with a variety of waste materials makes it a prime candidate for this program. The resulting composites have a higher modulus than those from organic matrices and are non-flammable. This makes the material applicable to high rise structures.

REINFORCEMENT CANDIDATES

The reinforcement candidates are dependent on the application of the composite. These applications can be divided for the purpose of this study into four basic categories.

1. Primary Structural Materials - These are materials that are used for transferring primary loads such as tension, compression and shear. Typical applications would be a load bearing wall surface, wall structural core such as a corrugation, roof surfaces, etc. Typical axial stress levels would range from 3,000 to 10,000 psi depending on design. Fiber reinforcements are the primary candidates. Glass roving, although not a waste, is inexpensive, available and can be used with any of the matrix selections. Paper is also an acceptable reinforcement but its availability is less at this time than glass roving. Kenaf, sisal, jute, and other such fibers also perform well but like paper are in short supply. For this study the candidates selected will be glass roving and waste paper.
2. Bearing and Framing Materials - These materials are used to transfer joint loads and close out openings. Typical applications are sill plates, window and door frames, roof and floor beams. Typical axial and bearing stress levels would range from 100 to 3000 psi depending on design. The reinforcing candidates selected are rice hulls, bark, plastic scrap, wood chips and cotton waste.
3. Secondary Structural Materials - These are materials used for non load bearing wall and ceiling panels.

Typical axial stress levels would range from 100 to 1000 psi depending on design. The reinforcing candidates selected are rice hulls, bark, wood chips and waste paper.

4. Floor Surface Materials - These materials are subjected to bearing and abrasion. The reinforcing candidates selected are waste paper, rice hulls, bark, and wood chips.

These candidates summarized in Table 9 were selected on the basis of properties, availability and economics of the composite to be designed.

Filler Candidates

The acid reaction of furfuryl alcohol requires the selection of non neutralizing fillers. Furfuraldehyde systems may be less demanding. Therefore, the Ph of the fillers may be important. The primary inorganic filler candidate is fly ash (Ph = 5.5). This permits its use with both the organic and inorganic matrix. The remaining inorganic candidates from Table 5 are not economically viable because of the limited locations of their sources. It is recommended that because of flammability only inorganic fillers be considered with organic matrices.

It is important to note that all of the final compositions from the inorganic matrices are non-flammable despite the utilization of large quantities of organic fillers and reinforcements. As a consequence, serious thought can be given

TABLE 9

Selected Reinforcing Candidates

<u>Reinforcement</u>	<u>Primary Structural Material</u>	<u>Bearing & Framing Materials</u>	<u>Secondary Structural Materials</u>	<u>Floor Surface Materials</u>
Glass Roving	X			
Waste Paper	X		X	X
Rice Hulls		X	X	X
Bark		X	X	X
Wood Chips		X	X	X
Plastic Scrap		X		
Cotton Waste		X		

to the use of scrap plastics extracted from dumps and manufacturers. Scrap styrofoam is a "natural" for formulation into syntactic foams. Other plastics of higher density could be made more suitable by shredding and/or grinding to increase surface area. The Thermoplastic resins are especially useful since they melt within their confinement in the inorganic matrix to produce a true foam from a syntactic foam. If scrap plastic can be so used in the construction industry the ecological and economic advantages would be considerable. This could eliminate, in many instances, the need for more costly photo degradable resins. This same fact permits the selection of wood bark, rice hulls, and saw dust as filler candidates for the inorganic matrix. (See Table 10)

TABLE 10
Selected Filler Candidates

<u>Filler</u>	<u>Organic Matrix</u>	<u>Inorganic Matrix</u>
Fly Ash	X	X
Plastic Scrap		X
Wood Bark		X
Rice Hulls		X
Sawdust		X

This phase will demonstrate potential, technical and economical feasibility. It will evaluate the potential for supply and qualify the selected candidates. This will be accomplished in the following sequential tasks.

A. Task I - Technical Feasibility of Product from Waste Materials

The MSC technical staff will evaluate through a material design, qualification and application engineering technique the potential products from waste materials.

This study will be limited to feasibility demonstration with laboratory samples of materials for specific applications. These samples will consist of panels and limited structural shapes. These samples will be subjected to tests for qualification to application. Such tests include water permeability, smoke generation, flame spread, mechanical properties, physical properties, etc. The material engineering approach will not necessarily be the optimum one, however, it shall be sufficient to determine practical feasibility or non-feasibility. This information will also be utilized to develop quantity and cost data.

This task will be accomplished in the following steps.

1. Development of Experimental Data - This effort will be directed primarily at the chemistry and processing of the matrix candidate. The reinforcement and filler candidates will be incorporated based on end product design and matrix characteristic. This will include the following.

a. Organic Matrix Chemistry - Develop with commercial chemicals the furfuraldehyde reaction with the phenols in wood.

b. Composite Processing with Organic Matrix - Using commercial chemicals and the developed chemistry fabricate specimens to develop processing techniques. These shall include but not be limited to the following.

1) 6" x 6" panels reinforced with residual wood and rice hulls.

2) Same as 1) except fly ash filler is added.

3) 6" x 6" panels reinforced with glass roving and with fly ash filler.

4) Same as 3) except paper replaces glass roving.

5) 2" x 4" blocks of foamed furfural-phenolic.

6) 2" x 4" blocks of furfural-phenolic mixed with rice hulls, with bark, with wood chips,

with plastic scrap and with cotton waste.

7) Same as 6) with addition of fly ash filler. These specimens will be visually evaluated and if considered acceptable submitted to the tests in Table 11.

c. Composite Processing with Inorganic Matrix -

The chemistry has been developed by MSC.

Therefore specimens will be fabricated to develop processing techniques for reinforcing with waste candidates and waste fillers.

These shall include but not be limited to the following.

- 1) 6" x 6" panels reinforced with glass roving with fillers of fly ash, plastic scrap, wood bark, rice hulls, and sawdust.
- 2) Same as 1) except foamed.
- 3) 2" x 4" blocks of inorganic matrix with fillers of fly ash, plastic scrap, wood bark, rice hulls, and sawdust.
- 4) Same as 3) except the inorganic matrix is foamed.

These specimens will be visually evaluated and if considered acceptable submitted to the tests in Table 11.

d. Organic Matrix Production Studies - Laboratory scale studies will be conducted to determine the feasibility of the proposed method of

TABLE 11

Laboratory Tests to be Conducted

Permeability
Smoke Generation
Flame Spread
Mechanical Properties
Thermal Properties
Accelerated Aging

developing furfuraldehyde direct from the rice hulls and reacting with the phenols from wood waste. These studies shall be conducted in sufficient depth to establish feasibility and projected costs.

e. Manufacturing Studies with Organic Matrix -

Limited studies will be conducted with MSC production machinery to determine the feasibility of continuous processing of the organic matrix with the different reinforcement and fillers. This activity shall be conducted in sufficient depth to establish feasibility of techniques and projection for the associated production costs.

f. Manufacturing Studies with Inorganic Matrix -

The same effort as described (e) will be conducted on the inorganic matrix, reinforcement and filler combinations.

g. Classification of Data - Review the above

generated data and classify each composite by category and rate excellent, good, fair, or poor. The categories are as follows:

- 1) Primary structural materials
- 2) Bearing and framing materials
- 3) Secondary structural materials
- 4) Floor surface materials

2. Adaptability to Code - Select those composites that have been rated excellent and good and review their qualification potential to federal and where applicable to state and local specifications, regulations and codes. From the Phase I study it is apparent that none of these materials will have been previously qualified. Therefore, the following will be accomplished.

- a. Requirements - Summarize the qualification requirements for each general category.
- b. Qualification Costs - Outline an acceptable test program for each category and estimate the cost.
- c. Qualification Time - Estimate the time for conducting each program.
- d. Cost Summary - Summarize the cost for each selected composite.
- e. Rating - Provide a numerical rating of the ability of each composite to qualify for each requirement. Sum up the total (T) for each composite to qualify for each specific program. Use a number 1 for a good rating in 1.g above and 3 for an excellent rating. Then compute a rating value (R) for each composite for each category as follows:

$$R = \frac{\text{Program Cost}}{(\text{T}) \times \text{Rating from 1.g}}$$

Only those with lower R values will be considered for further studies.

3. Quantity Utilization/Availability - Determine for the materials with the lower R values the quantity (volume, weight, etc.) of waste materials (before and after processing) that are required for the material category.
 - a. Select from 2 above those items that are near term qualification and application (0 to 2 years) and from the quantity take off.
 - 1) The quantity of raw waste by constituent,
 - 2) The quantity of processed waste by constituent,
 - 3) The projected availability of the waste supply and,
 - 4) The distribution of the waste supply.
 - b. Select from 2 above those items that offer potential qualification and application within the next five years and from the quantity take off.
 - 1) The quantity of raw waste by constituent,
 - 2) The quantity of processed waste by constituent,
 - 3) The projected availability of the waste supply, and
 - 4) The distribution of the waste supply.

4. Category of Construction - The above materials will then be classified as potential construction components as follows.

a. Elements

- 1) Skins - wall (interior, exterior), floor, roof, ceiling
- 2) Core
- 3) Insulation
- 4) Finish elements
- 5) Pipe
- 6) Sealants

b. Components

- 1) Wall panel exterior
- 2) Wall panel interior
- 3) Roof Panel
- 4) Roof/ceiling panel
- 5) Ceiling panel
- 6) Floor panel
- 7) Floor/ceiling panel

B. Task II - Determination of the Economic/Cost Effectiveness of Utilizing Waste Materials for Building Products

1. Development Costs - Develop those costs associated with product development and the time required.

- a. Develop practical factors to be applied to projections for cost, time and product life. These factors shall include the following:

- 1) Development to production process factor
- 2) Qualification factor
- 3) Application factor
- 4) Acceptance factor

2. Product Cost - The cost of the product delivered to the construction site will be developed as the product cost F.O.B. factory and transportation costs.

a. Products costs F.O.B. factory will be developed.

- 1) The cost for existing or near available waste materials will be established by surveying the suppliers.
- 2) The cost for waste material in recovery development will be established by the following procedure.
 - a) Projections will be collected from suppliers.
 - b) These projections will be screened for adequacy of assumption and correction factors.
 - c) Where projections are not available MSC will make estimates based on constituents and apply applicable factors.
- 3) The cost for potential waste materials will be developed by the following procedure.
 - a) MSC will make projections based on constituents and apply applicable factors.

b) MSC will estimate the cost for development, qualifications and production start-up. These costs will be amortized over a reasonable period and then apply the cost to that of the product projection.

b. Transportation Costs - Are market and facility dependent. These costs will be based on the following approach.

1) Market facility inter-relation will be developed for the more promising products.

a) Determine those markets and products that can be serviced from multiple low cost facilities. This results in limited transit cycles.

b) Determine those markets and products that can be serviced only from singular high cost facilities. This results in long transit cycles.

2) The relationship of weight and volume for each product will be established.

3) Compute transportation cost for the more promising products utilizing the effect of transit cycles and packaging factors from 1 and 2 above.

3. Installation Costs - For the new product will be developed and compared with the existing standard product. This will be accomplished as follows.

- a. Determine installation costs for the standard product under study.
 - b. Summarize those substitute products that can be installed by the same methods as the standard product.
 - c. Develop conceptual methods for installing products that require different installation techniques.
 - d. Evaluate local union and trade requirements regarding skills of installers.
 - e. Estimate the installation costs of those products requiring different installation procedures on the basis of information developed in b, c, and d above.
 - f. Compare the costs developed in e with those summarized in a.
4. Estimate the product life characteristics of the composite waste material product on the basis of duration, maintenance, and economics.
- a. The products to be analyzed will be classified as to application and applicable performance specifications. These data are available from Tasks I.
 - b. An economic analysis conducted by marketing will be made for each applicable product.

- c. Summarize the economic impact on the industry involved and any effects it may have on the product utilization.

C. Task III - Development of Data on the Supply of Waste

- 1. Determine the demand requirements for waste material.
This will be accomplished by the following procedures.
 - a. Categorize the products by application (Task I) and the type of waste and composition (Task I).
 - b. From Task I summarize the quantities of waste required before and after processing by type for each application.
- 2. Determine the potential supply for the waste material required.
 - a. Summarize the present supply and projected supply for each type of waste required.
 - b. Geographically locate the density of the generated waste material.
 - c. Note any projected changes in life styles, processes, etc. that may markedly effect the quantity of waste generation.

D. Task IV - Qualification of Materials Under Existing Codes

- 1. Selection - Based on the above studies select up to three systems or combinations that have the greatest application potential.

2. Qualification - This will be accomplished as follows.

- a. Construct the necessary panels or elements.
- b. Conduct the required tests.
- c. Submit the data for qualification to the appropriate agencies.
- d. Coordinate the evaluation by the agency through the providing of additional data when required.

APPENDIX A

SAMPLES OF COLLECTED DATA

SOLID WASTE INFORMATION RETRIEVAL SYSTEM

CATEGORY CODE: 07

ACCESSION NUMBER: 024938

CITATION: Stahly, E.E. Novel methods of polymer disposal. Presented at the Symposium on the Disposal and Utilization of Plastics, Summer Institute in Science and Technology, State University College, New Paltz, New York, June 25, 1973. 24 p.

ABSTRACT: This paper was delivered at the Symposium on the Disposal and Utilization of Plastics which was sponsored by the U.S. Environmental Protection Agency. It discusses various methods of disposing of plastic wastes. Over 80 percent of polymers are incinerated or used in landfills. There are no quick solutions to polymer disposal problems by useful reclamation or any other new methods. Continuing increases in energy needs and decreasing supplies of fuels make it quite possible that combustion of polymers can be an important economic source of power. The present economically feasible methods of disposal of waste polymers are recycle and reclamation (5 percent), fillers for roads (25 percent), reefs and road abutments (5 percent), and soil conditioners (5 percent). Within the next 10 years much of the remaining 60 percent of waste polymers may be used as fuels. This depends on continued outlay of effort and funds to develop reclamation methods to the point of utility. (This document is retained in the SWIRS library.)

KEYWORDS: DISPOSAL
PLASTIC
CONFERENCE
BIBLIOGRAPHY
PROCESS
UTILIZE
DISTILLATION
ECONOMICS

POLYMER
INDUSTRY
EPA
DATA
CONSTRUCTION
FUEL
OXIDATION

NOTICE OF RESEARCH PROJECT

SUPPORTING AGENCY		AGENCY'S NUMBER(S)	
AGRICULTURE DEPARTMENT COOPERATIVE STATE RES. SERVICE CALIFORNIA		0011564 CA-F#-FPL-2495-MS	
TITLE OF PROJECT		Reproduced from best available copy. R/M	
CHEMISTRY AND UTILIZATION OF BARK			
PRINCIPAL INVESTIGATOR, ASSOCIATES AND DEPARTMENT/SPECIALTY:			
AB ANDERSON		MCINTIRE STENNIS PROGRAM	
RECIPIENT INSTITUTION		PERIOD FOR THIS NRP	
UNIV. OF CALIFORNIA AGRICULTURAL EXPERIMENT STA. BERKELEY, CALIFORNIA 94720		7/72 TO 6/73 MULT.SUPPORT FY73 FUNDS UNKNOWN	

SUMMARY OF PROJECT

OBJECTIVE: Determine the chemical nature of the various components of bark and ascertain whether they have potential application in industry, agriculture, and chemotherapy.

APPROACH: The barks will be analyzed for the quantity and nature of the extractive components, as well as alkaline solubles. The extracted bark residues, as well as whole bark, will be evaluated as raw material for composition boards and the extracted bark residues as soil conditioners. Species comprise tanoak and major California conifers, except Douglas-fir.

PROGRESS: Bark particle boards have been produced without the addition of the usual bonding & sizing agents. This was accomplished by the addition of certain agents, such as paraformaldehyde, or hexamethylenetetramine to the bark particles. These agents react with the-tannin (polyphenolics) in the bark during the hot press cycle, forming a bonding agent, in situ. The bark boards so formed have internal bond values which meet the requirements of commercial standards for wood particle board. A remarkable property of the boards is thickness swelling, representing about half of the value permitted for normal particle board. Further while the normal wood particle board disintegrates during the boiling water test, the bark board remains intact with little swelling even after the 2-hour boiling water test. Thus in addition to forming a good internal bond, the bonding is waterproof. Since the catechol type of polyphenolics in barks are very reactive, it was of interest to determine the effect of other agents such as acids, bases & oxidizing agents. The reagents examined were paraformaldehyde, hexamethylenetetramine, nitric acid, hydrochloric acid, sodium hydroxide, ammonium hydroxide, hydrogen peroxide, ferric chloride, ammonium nitrate & sodium chlorate. The barks investigated include white fir, Douglas fir, ponderosa pine & sugar pine. Each of these reagents reacted to form a bonding agent in the preparation of bark particle board. The correlation between specific gravity & basic physical properties of composite bark boards made with optimal reagent were determined. A report on the findings is in preparation.

"Ash in Road Building"
Ash at Work, 11(3):1, 3, 1970

Flyash was approved by the Minnesota Highway Department for use as common borrow in embankments on a project to bridge railroad tracks in St. Paul. Characteristics of ash from a nearby power plant were as follows: 90% silt size (under 200 mesh); moisture content, 27%; and dry density, 85.7 lb/cu ft. (Sand has a 110 to 125 lb/cu ft density; and silt, 110 lb/cu ft.) The state of Ohio has decided to place a pozzolanic base containing flyash under continuous reinforced concrete road surfaces in six state projects to date. In Great Britain, over 1,000,000 tons of flyash will be hauled 75 miles from the Aberthaw power plant in South Wales to a construction site near Somerset for use in the construction of a 17-mile section of the new M5 expressway. The ash is being used for structural fill on embankments for 14 bridges and 2 interchanges on a section of a highway which runs through peaty land having a poor bearing capacity. Boiler slag was used in the construction of a 5.73-mile experimental strip of highway in West Virginia. Apparently, the slag imparted a distinctly "non-skid" characteristic to the surface.

Eye, J. D. and T. K. Basu

"The Use of Flyash in Wastewater Treatment and Sludge Conditioning"
J. Water Pollution Control Fed., (Research Supplement); 42(5):
R125 - R135, May 1970

In addition to its cheapness and readiness of availability, characteristics of flyash which make it useful as an adsorbent in wastewater treatment are the large surface area per unit of volume of particles and their carbon content. From 20% to 40% of the ash by weight has a particle diameter of less than 10 μ ; and 80% to 90%, a diameter of less than 200 μ . It weighs about 30 lb/cu ft. The carbon content varies from 1% to 60%. Flyash particles used in the study were almost spherical in shape, less than 10 μ in diameter; and had a carbon content from 4.2% to 23.3%; a specific gravity from 2.1 to 2.55, and a specific surface area of 2,970 to 6,420 sq cm/g.

From the results of their study the authors conclude that: 1) Flyash is capable of reducing the COD of secondary effluent by about 30% at a flyash concentration of about 1,600 mg/l and an initial COD of 60 mg/l. The extent of removal is greater when a wastewater having a higher COD is processed. 2) "Removal of suspended solids containing flyash by coagulation with lime is highly efficient." At an overflow rate of 330 gpd/sq ft, about 98% of suspended solids were removed. 3) Flyash serves as a useful sludge conditioner for vacuum filtration.

FEEDSTUFF PRODUCTION

Anthony, W. B.

"Cattle Manure: Re-Use Through Wastelage Feeding"
Animal Waste Management - a collection of papers presented before
the Cornell University Conf. on Solid Waste Management, Syracuse,
N. Y., pp. 105-113, January 13-15, 1969

The chemical composition of organic wastes from ruminants is quite comparable to that of the feed ingested by the animals. Moreover, the wastes are enriched by the presence of an abundance of rumen microbial matter. As voided

99.82 P95 ID NO.- 73-9155440 197254 R

Przykład wykorzystania odpadów drzewnych do produkcji zastępczych materiałów budowlanych; An example of the utilization of wood waste in the production of substitutes for building industry

LANGUAGE- POL

Kobyliński, F

Przem Drzewny 23 (5): 35-36. May 1972

DESCRIPTORS- Poland

CAT CODE- 352000

SEARCH- 19720500

DOC TYPE- ARTICLE

99.8 W89 ID NO.- 73-9147973 190241

New Finnish board plant utilizes mill waste

Jyrkinen, N

World Wood 14 (2): 10-11. Feb 1973

DESCRIPTORS- Finland

CAT CODE- 352000

SEARCH- 19730200

DOC TYPE- ARTICLE

TD899.P3C6 ID NO.- 72-9343779 156504

Combined treatment of municipal kraft linerboard, and fiberboard manufacturing wastes

Clark, Edward A

Macon, Georgia, Board of Water Commissioners; Georgia Kraft Company; Armstrong Cork Company; U.S., Environmental Protection Agency

Washington, U.S. Govt. Print. Off. 131 p. illus. 1971

SEARCH- 19710000

DOC TYPE- MONOGRAPH

TP996.B3C3 ID NO.- 72-9345400 153443

Construction of a chemical-microbial pilot plant for production of single-cell protein from cellulosic wastes

Callihan, C D; Dunlap, C E

U.S., Environmental Protection Agency; Louisiana State University and Agricultural and Mechanical College

Washington, U.S. Govt. Print. Off.. 126 p. illus. 1971

SEARCH- 19710000

DOC TYPE- MONOGRAPH

99.8 IN2 ID NO.- 72-9108957 135213 R

Fibrous raw materials for the Indian pulp, paper and board industry

Guha, S R D; Pant, R

Indian Forest 98 (7): 409-426. July 1972

CAT CODE- 352000

SEARCH- 19720700

DOC TYPE- ARTICLE

APPENDIX B

EXAMPLES OF DATA REQUESTS

March 1, 1974

Texas Technological University
School of Engineering
P.O. Box 4340
Lubbock, Texas 79409

Attn: Professor H.W. Parker
Chemical Engineering

Subj: EPA Contract 72P20313 - Methods for Disposal, Processing
and Use of Animal Waste.

Dear Professor Parker:

Material Systems Corporation has developed a series of composite materials for use in housing construction. The primary one utilized in the United States consists of glass fibers, alumina powder, and a polyester binder. In Mexico we use henequen fibers, volcanic ash and a polyester binder. We are actively seeking substitutes for all three elements. To facilitate this search we have entered into a joint venture contract with the Solid and Hazardous Waste Research Laboratory of EPA in Cincinnati, Ohio. Mr. Charles Rogers is the Project Officer. They are conducting a literature and program survey and we in turn will use this survey to seek new sources, conduct the necessary materials evaluation and research for building material application.

We are, therefore, interested in your program. It would appear from the limited studies that we have made, that it is feasible to utilize animal waste as a binder, a filler and a reinforcement. The process that appears applicable is to pass the waste through pressure rollers and then through ovens. We are now processing 60,000 pounds of our standard composite per machine per month. Therefore, the raw material source must be one that is reliable and collectable.

Have you done any work along this line? If not, do you think it is practical? In any case we would appreciate any information you could provide us on the subject. If a mutual

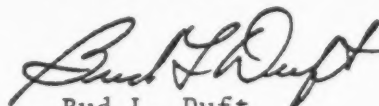
Page 2
Duft/Parker
1 March 74

interest can be achieved, MSC would be interested in working with Texas Tech on the subject.

As an introduction to our company, I am attaching photos of some of the units built from MSC composite materials. Over 200 units have been constructed in the United States to date. MSC also has 500 more units assigned to it by HUD. Prototypes have been built in Mexico City and Paris, France. MSC has also licensed the process in Iran, France and Mexico. We have an excellent applied science staff of over 50 people and are actively working on new products.

We are looking forward to your answer and hope we have an area of mutual interest.

Sincerely,

A handwritten signature in cursive script, appearing to read "Bud L. Duft".

Bud L. Duft
President

BLD/b

March 6, 1974

University of Georgia
Agricultural Experiment Station
Athens, Georgia 30601

Attn: J.T. Rice
R.H. Page
C.M. Chen

Subj: Influence of Wood Characteristics on the Processing
and Properties of Reconstituted Products

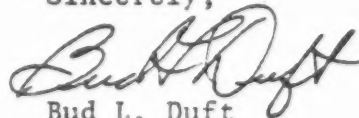
Gentlemen:

Material Systems Corporation is a producer of structural wall panels for residential housing. These panels are produced on automated equipment from a composite of fibers, fillers, and binders. The composite being utilized in the United States is glass fibers, calcium carbonate, and polyester resin. In Mexico sisal fibers are used to replace the glass.

We have initiated an intensive research effort to replace all of the constituents from waste derived materials and have entered in a joint venture contract with the Environmental Protection Agencies' Solid and Hazardous Waste Research Laboratory to help facilitate the program. Through this, your program was brought to our attention as a potential contributor.

We would appreciate any information you might be able to provide on fiber, filler, or binder candidates. The quantities and availability are also important. Each machine requires 475,000 pounds of constituents per month per machine per shift. If you are actively pursuing this type of study it might be possible for MSC to establish some form of joint activity with you. In this regards, you are cordially invited to visit our facilities in Escondido, California. Thanks in advance for your assistance.

Sincerely,



Bud L. Duft
President

APPENDIX C

MATRIX

M-001-DAS Protein Glue - F.B. Weakley USDA - Peoria, Illinois

The dialdehyde starches are reactive with protein type materials and will cross-link them. Such substrates include animal blood and casein. In the event we find waste products rich in protein structures, i.e. polypeptides, then I recommend looking into this class of material. I foresee little, if any, useful reaction with cellulose or carbohydrate type chemical structures.

M-002-Fuels and Petrochemicals from Agricultural Waste-
H.W. Parker, 76th National AIChE Meeting, March 1974

Manure consists of water, ash, lignin, and cellulose. Lignin can be more economically derived from paper mills. Cellulose can be derived more economically from wood pulp. The material can then best be used for fuel or feed stocks. The collection cost and effective radius either results in an uneconomically small plant for economic collection or uneconomical collection over a large radius for an efficient sized plant.

Manure can be processed as other agricultural wastes into fufural and furfuryl alcohols. This is a potential matrix material. Table 1 shows a distribution of available waste. Manure and agriculture crop and food wastes are 67% of the total generated waste.

TABLE 1

Estimates of Available Organic Wastes, 1971 (Anderson, 1972)

		Total organic wastes generated	Organic solids available
Source:			
Manure.	million tons/year	200	26.0
Urban refuse.	do	129	71.0
Logging and wood manufacturing residues.	do	55	5.0
Agriculture crops and food wastes	do	390	22.6
Industrial wastes	do	44	5.2
Municipal sewage solids	do	12	1.5
Miscellaneous organic wastes.	do	50	5.0
Total	do	880	136.3

SOUTHWEST RESEARCH INSTITUTE

8500 CULEBRA ROAD • POST OFFICE DRAWER 28510 • SAN ANTONIO, TEXAS 78284

Department of Materials Sciences

March 19, 1974

Mr. Bud L. Duft, President
Material Systems Corporation
751 Citracado Parkway
Escondido, CA 92025

Dear Mr. Duft:

Glen Grimes has forwarded your letter to me for reply. I am enclosing a couple of data summary sheets that briefly review the products which you have expressed interest in. If either of these looks interesting to you, give us a call and we'll be happy to discuss them in detail.

Another undisclosed area of possible interest is our development of foam-in-place silicate foams capable of replacing the plastic foams or protecting them from fire. The silicate foams vary in composition according to end use, but they are generally all capable of superior fire protection (2200°F stability for indefinite periods) exhibit excellent insulation properties (.22 @ 4 - 5 PCF to 0.32 at 15 PCF @ 75°F - BTU in/ft²/hr/°F) and may be produced at prices which compete with fiberglass.

We are committed to a client in a license agreement, but there may be opportunities for sub-licensing if you are interested.

Yours very truly,

WAM

William A. Mallow
Group Leader

WAM/ag Bud: The geothermal cements are of interest as ~~are~~ is quick-setting concrete. Could we evaluate accelerator alone under secrecy agreement
Enc. 2 Then some arrangement if it works with our "OX" system?
Both cements with proper fillers to reduce weight might be useful in composites.

Harold
The foam seems promising but sub-license may be to someone already in construction. Could we find out who has this arrangement?



SOUTHWEST RESEARCH INSTITUTE

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REVIEW OF SwRI ACTIVITIES IN GEOTHERMAL-RELATED TECHNOLOGIES

Southwest Research Institute (SwRI) has developed a unique family of hydrothermal cements designed to accommodate the high-temperature environment of deep-hole, nuclear-stimulated gas wells. A recent field application test was conducted in a 6500 ft. well in Texas, where approximately 500 ft.³ of this new material was used to secure the steel casings which deliver the payload and stabilize the well structure. The cement was designed to harden only at temperatures above a specific threshold, in this case of 150°F. The cement exceeded all expectations.

A family of cements is available whose slurries are indefinitely pumpable at temperatures below their respective initiation thresholds of 100, 135, 150, 225, and 300°F. In addition, the cured cements capable of withstanding service temperatures above 1000°F without alteration in physical and mechanical properties. Compression strengths of 3,000 to 20,000 psi are possible -- projected economics of these cements is very closely competitive with modified portland cements currently used in much less demanding oil and gas well environments. Their adhesion to steel and other metals is phenomenal compared to conventional oil well cements. Shear bonds of 1300 psi are typical, using smooth and polished mild steel surfaces for testing. This compares to a 500 psi shear bond strength of portland cement with "re-bar" or 150 psi under conditions used with this novel cement.

We feel that such a family of cements and concrete products is potentially valuable to the geothermal technology, and would like to take this opportunity to introduce our product and expertise in this newly acquired domain to those who are in need of such a material.

The following data summarize the essential qualities and properties of SwRI hydrothermal cements.



SAN ANTONIO, HOUSTON, CORPUS CHRISTI, TEXAS, AND WASHINGTON, D.C.

PROPERTIES OF SwRI HYDROTHERMAL CEMENTS

1. Composition

Natural minerals
Commercially available filler
Inexpensive, low-energy-demand chemicals

2. Initiation Temperature (below which no physical or chemical change occurs)

100, 135, 150, 225, 300, and 425°F for six typical formulations

3. Volume change upon cure - expansive

4. Rheology of cement slurry: thixotropic, very easily pumped with conventional equipment

5. Mechanical Properties

Compressive strength - 7 days/initiation temperature
for most economic systems 3,000-10,000 psi
for more exotic systems 10,000-20,000 psi

Shear bond strength - 7 days/initiation temperature
1,000-1,500 psi

6. Chemical Properties

Resists oils, acids, and organic solvents. Fresh slurry resists water loss or dilution. The slurry does not lose or gain water when exposed to clay or soils.

7. Thermal Qualities

Cured cement/concretes withstand continuous exposure to dehydrating or autoclave heating at temperatures of 1,000-2,000°F, depending upon formulation.

8. Economics

Low material cost - bulk rates:
Most versatile and all-purpose recipe will average \$3.00/ft³

SOUTHWEST RESEARCH INSTITUTE

QUICK-SETTING CONCRETE

Southwest Research Institute has developed a fast curing concrete based upon Portland cement which achieves up to 1500 psi compressive strength in one hour and over 10,000 psi in 18 months. (The SwRI formulated cement expands slightly upon setting, and shrinkage has never been observed.) It is highly acid resistant, sulfate ion resistant, unaffected by freeze-thaw cycling, and non-corrosive to metals. The fast setting formulation yields a mortar which is lower in permeability to water vapor, air, etc. than the conventional cements and requires no re-wetting during cure under normal conditions. Gel time or set times of 20 to 30 minutes, depending upon environmental temperature and formulation, are easily accommodated and means of shortening or extending the early set are available in the present state of the art.

The accelerator is a readily available, inexpensive material, non-toxic and perfectly safe to handle. In the present art the additive is dissolved in water and introduced as a solution, but it may be possible to offer the accelerator as an inherent component to the dry cement to which ordinary water may be added in the conventional manner. Aqueous solutions of the accelerator have indefinite shelf life and the solutions are stable down to 5°C without separation. The quick-set cement formulation can be enhanced by the addition of 30 parts of flyash per 100 parts of cement. This also has the effect of reducing the cost of the accelerator. At present bulk prices, the quick-cure formulation would impose a 19% increase in the cost of typical concrete formulations (1:2:4).

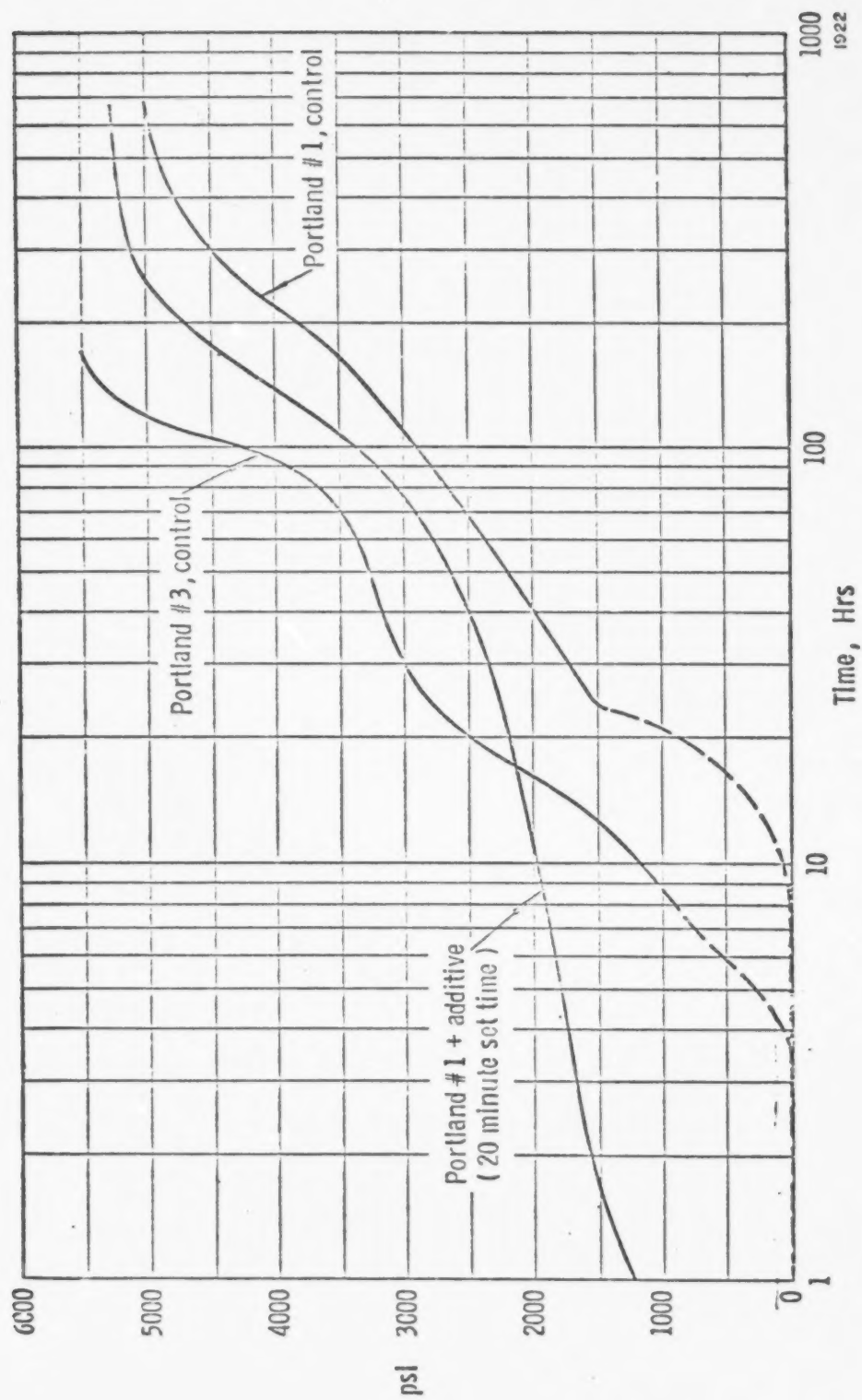
Compression strength versus time has been plotted and the curves are enclosed. The comparison of quick-set cement and conventional mortar formulations were derived from preparations following ASTM C-109 practices. The quick-set cubes were aged for 25 hours in 72°F water and stored in ambient lab environment (72°F/50% relative humidity), during the remainder of the test period.

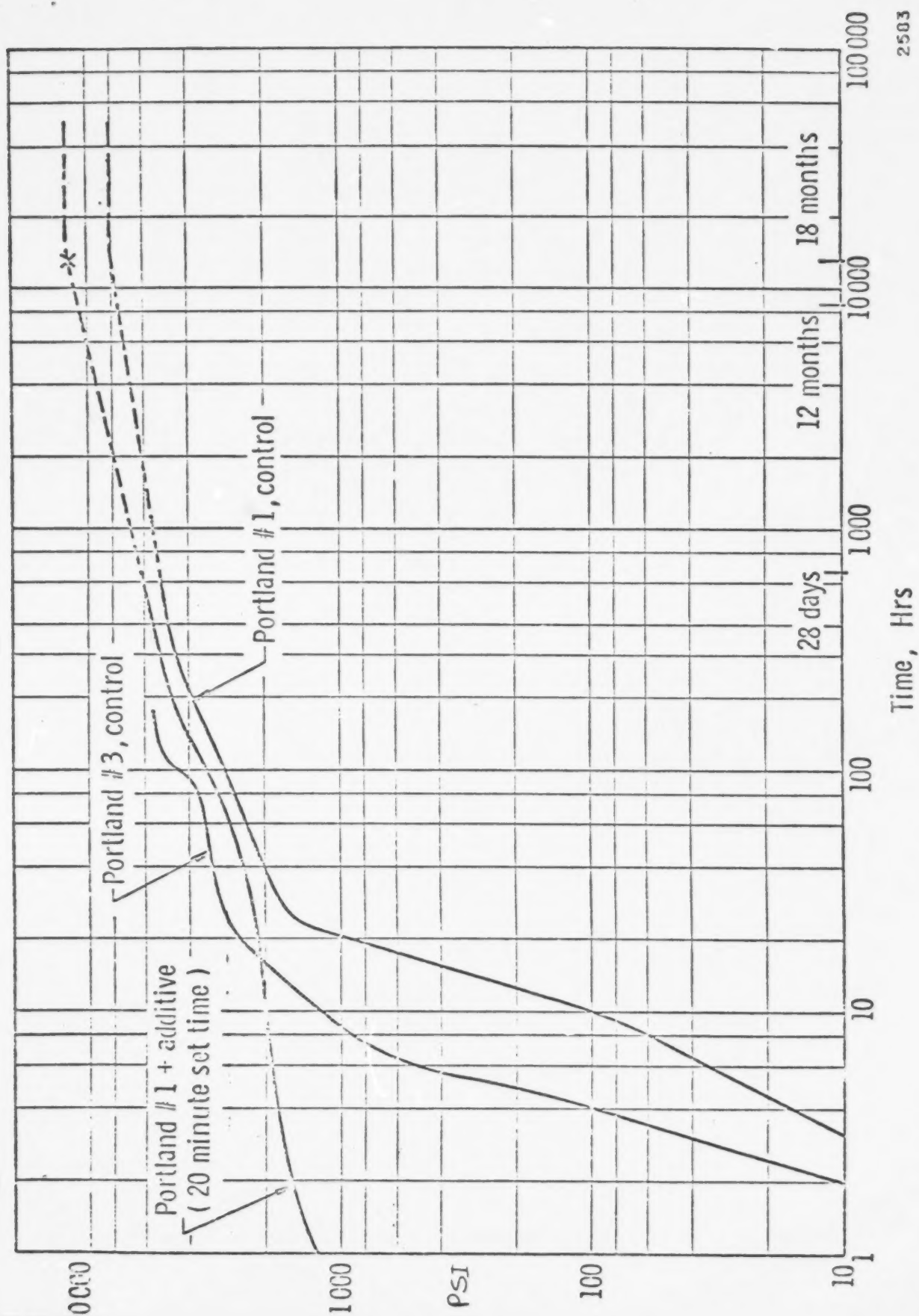
Among the many applications for this material are the following:

1. Cement pipe production
2. Road and runway repair
3. Soil cement, grouting, etc.
4. Brick and tile production

- 9
5. Terrazo flooring
 6. Promenade decks
 7. Lightweight aggregate production on a continous basis.
 8. Coal mine stabilization
 9. Underwater structures
 10. Casting of ornaments, statues, etc.
 11. Shot-Creting

Southwest Research Institute is a contract oriented organization and we would be more than happy to work with government or commercial agencies toward further development of this material for specific applications.





2503

M-004-Possible Uses for Waste Rice Hulls In Building Materials
and Other Products - J.H. Hough, H.T. Barr, Bulletin No. 507
Agricultural Experiment Station, Louisiana State University
and A & M College

Rice hulls have been used as a reinforcement for adobe blocks, slump brick, and concrete. The ground hulls and ash have been used as filler for resins. The high silica content of the hulls are hard on machinery.

Rice hulls can also be used to manufacture furfural for use as a resin.

They can also be used for insulation.

The availability and composition of rice hulls and ash are presented below.

Approximate Analysis of Rice Hulls
(All varieties)

Moisture	8.49% to 11.00%
Ash	15.68% to 18.59%
Ash (Insoluble in 10% HCl)	14.50% to 17.52%
Crude protein	2.94% to 3.62%
Ether soluble extract	0.82% to 1.20%
Crude fiber	39.05% to 42.90%
Nitrogen free extract	24.70% to 29.38%

Typical Chemical Analysis of Rice Hull Ash

Silica (SiO ₂)	94.50%
Calcium oxide (CaO)	0.25%
Magnesium oxide (MgO)	0.23%
Potassium oxide (K ₂ O)	1.10%
Sodium oxide (Na ₂ O)	0.78%
Phosphoric oxide (P ₂ O ₅)	0.53%
Sulphates (SO ₃)	1.13%
Aluminum, manganese, ferric oxides (Al, Fe, Mn)	Traces

	Rice	Rice Hulls	Ash
Arkansas	744,440 tons	126,555 tons	25,311 tons
California	529,495 tons	90,014 tons	18,003 tons
Louisiana	719,432 tons	122,303 tons	24,460 tons
Mississippi	142,547 tons	24,235 tons	4,847 tons
Texas	806,582 tons	137,119 tons	27,424 tons
TOTAL	2,942,496 tons	500,224 tons	100,045 tons

13

M-005-R-015-The Chemical Conversion of Solid Waste to Useful
Products-J.F. Barbour, R.R. Groner, Dept of
Agricultural Chemistry, Oregon State University

All solid wastes contain a large percentage of cellulose. The cellulose can be reacted upon to produce particle board, fibers, and other chemicals. Under certain conditions the waste material such as straw can be partially reacted where the cellulose acts as the binder and the remaining particles the reinforcement.

Full reactions of straw, paper and other materials have been used to form cellulose acetate which is then passed through orifices to form fibers.

Important tables are presented. This has potential for both fiber and matrix.

Table II. B. 1. Composition of Typical Municipal Refuse as Reported by
Kaiser (13).

Category	Weight Percent
Paper	53.46
Corrugated paper boxes	23.38
Newspaper	9.40
Magazine paper	6.80
Brown paper	5.57
Mail	2.75
Paper food cartons	2.06
Tissue paper	1.98
Wax cartons	0.26
Plastic coated paper	0.76
Moisture	9.05
Garbage	8.40
Vegetable food wastes	2.29
Citrus rinds & seeds	1.53
Meat scraps, cooked	2.29
Fried fats	2.29
Glass, Ceramics, Ash	7.73
Vegetation	
Ripe tree leaves	2.29
Flower garden plants	1.53
Lawn grass green	1.53
Evergreen	1.53
Metals	6.85
Miscellaneous	7.62
Wood	2.29
Plastics	0.76
Rags	0.76
Leather goods	0.38
Rubber compositoon	0.38
Paint and oils	0.76
Vacuum cleaner catch	0.76
Dirt	1.53
Total	99.99

Table II. B. 4. Estimate of Industrial Waste Composition in Oregon

	Volume Percent									
	Paper Waste	Wood Waste	Metal Waste	Animal Waste	Textile Waste	Petro-Chemcl	Fruit Vegtbl	Rubber Plastic	Sand, stn Glass, Ash	
Meat Processing	97	3	>1					1		
Electric Machinery	97	1						3	1	
Dairy Products	96	>1					3		>1	
Misc. Food Processes	94	1								
Printing & Publication	94	4	1			>1				
Petroleum & Allied	92	5						5	3	
Scientific Instrument	88	5	1		>1	>1				
Ordnance	85	11	1			2				
Non-Elec. Machinery	82	13	3					2		
Processed Foods	70	>1	5				23	2		
Apparel Products	69	1	1		28			2		
Rubber & Plastics	69	13	1		1	>1		1		
Chemical & Allied	60	27	8			8		16	1	
Transportation	58	40	1		1				<1	
Misc. Manufacturing	57							43		
Cannery & Frozen	56	3	2			>1	39	>1	<1	
Textile Mills	54	2	1		42	>1		>1	<1	
Furniture	52	39	4		3			1	1	
Stone, Clay & Glass	44	40	5			>1		>1		
Seafood Processing	43	13	10	33				1		
Fabricated Metals	43	43	14						47	
Primary Metals	30	7	15			>1			<1	
Wood Products	27	65	6			1		1	<1	
Paper & Allied	25	4	1							
Leather Manufacture	14	2	4	72	>3			3	2	

Table II. B. 7. Composition of Cereal Straws

wt.%, dry basis

Component	Oat min. - max.	Rice min. - max.	Wheat min. - max.
Dry matter	83.9 - 95.2	88.8 - 93.4	82.8 - 99.1
Cellulose	40.1		35.3 - 63.9
Lignin	13.4 - 15.8		12.4 - 15.1
Pentosans		17.7	10.2 - 12.8
Crude protein	2.0 - 8.6	2.8 - 6.2	1.5 - 6.9
Crude fat	0.8 - 3.2	8.7 - 2.3	1.0 - 3.7
Crude fiber	33.3 - 54.0	27.6 - 38.3	36.4 - 51.5
Ash	4.9 - 12.9	14.0 - 20.1	3.5 - 11.1
Sulfur	0.20 - 0.27		0.13 - 0.29
Sodium	0.23 - 0.53	0.31	0.06 - 0.23
Chlorine	0.70 - 0.85		0.21 - 0.34
Calcium	0.13 - 0.40	0.15 - 0.38	0.10 - 0.42
Phosphorus	0.15 - 0.43	0.06 - 0.15	0.04 - 0.51
Potassium	0.20 - 2.41	1.10 - 1.51	0.12 - 1.95
Magnesium	0.16 - 1.48	0.07 - 0.18	0.05 - 0.70
Iron	0.018- 0.056		0.007- 0.017

17

Table II. B. 8. Composition of Grass Seed Straws
wt.%, dry basis

Component	Fine Chewings Fescue	Merion Bluegrass	Highland Bentgrass	Perennial Ryegrass	Annual Ryegrass
Crude protein	5.2	9.1	4.6	5.5	4.5
Crude fiber	45.1	36.6	39.4	41.2	40.2
Crude fat	1.8	2.1	1.9	1.8	1.4
Crude pectin	1.1	1.6	1.7	2.3	1.8
Ash	7.0	5.4	2.7	6.7	6.6
Total sugars	0.20	2.49	2.01	0.68	4.05
Reducing sugars	0.17	1.74	0.96	0.43	3.25
Pentosans	27.1	24.0	24.8	22.0	23.7
Lignin	10.2	8.7	9.0	8.8	8.6
Cellulose	45.2	41.6	44.2	42.3	42.8

This study evaluated mechanisms for the cohesive bonding of Douglas fir bark particles without additional matrix. Covalent chemical bonds result from sharing or exchange of electrons between atoms. Such bonds could result from polymerization of the phenolic extractives which comprise as much as 40 per cent of the bark. This has been reported at temperatures in excess of 400⁰F. Physical bonding was also a possibility.

The study showed that the bond is due principally to thermoplastic flow and consolidation of the cork particles. Therefore, boards of this nature would creep with time or at an elevated temperature.

M-007-Mill Evaluation of Dialdehyde Starch-Protein Glue for
Hardwood Plywood Manufacture-F.B. Weakley, W.B. Roth,
Forest Products Journal Vol 23 No 7 July, 1973

DAS-protein glue was evaluated on a mill scale. The glue worked well. It reduced press time, did not produce any irritating fumes, and was easy to clean up.

Bulletin #507 June 1956 - Possible Uses of Waste Rice Hulls

Majority of work involved with use of rice hull ash after incineration (contains 94.5 % silica). The booklet details several uses, none of which approach the MSC work. All previous use to make lightweight concrete never seemed to be successful for a variety of reasons. A 3 year study at LSU culminated on a conclusion that concrete containing rice hulls and rice hull ash could not be recommended as a building material because of poor economics and stability. However, it had better insulating behavior and weaker strength; such a material could be used for non-structural purposes. Some success was obtained in making soil-bricks but bricks are of lesser interest to MSC since they have poorer cost effectiveness than FRP panels. Of interest to MSC is the use of rice hulls to prepare and use furfural "in situ" with phenol containing wood particles.

21
M-009-Furfural From Bagasse, C.I. Nee & W.C. Hsich

Int. Soc. Sugar Cane Tech. Proc. Cong. 13th 1881-1890 (1970)

This was an excellent article giving much information that can be of use to MSC if we embark on a program to make and use furfural "in situ".

It is a discredit to chemists and chemical engineers that so little of the noncellulosic part of wood finds its way into chemical products, illustrating a neglect of research priorities that is difficult to understand. Effective use of the residues left after kraft and bisulfite treating for wood pulp would create an industry with roughly the tonnage of the steel industry.

Most lignin is burned, but approximately 20% of the sulfite waste liquor production is sold as either sodium or calcium lignosulfonate. These materials are employed for a wide variety of purposes, but uses of broad scope and large size are not yet at hand. Both the sodium and calcium salts are byproducts of pulp manufacture and are marketed not so much for their value as chemicals but to avoid difficult waste-disposal problems. The waste liquors are concentrated and sold as solutions or spray or drum dried.

Uses for these materials, based on their surfactant and chelating properties, include: grinding aids, oilwell drilling-mud suspenders (largest single use), road binders, animal-feed pelletizing agents, leather-tanning agents, ore-flotation agents, protein-precipitating agents, ceiling-tile binders, charcoal-briquetting agents, emulsion stabilizers, cement additives, metallic-ion complexing agents for agricultural use, boiler-

M-010 2nd page continued

scale inhibitors, storage-battery-paste additives, ingot-mold wash, lime-plaster additive, and an additive in electrolytic refining.

In 1970, the sodium salt was marketed by five U.S. companies (Crown Zellerbach, American Can, ITT-Rayonier, Sonoco Products, and Westvaco) at a price of 9¢/lb. It is currently quoted at 4.75¢/lb. The calcium salt was offered by six U.S. companies (Crown Zellerbach, Consolidated Paper, Glyco Chemicals, Lake State Div. of St. Regis, American Can, and Georgia-Pacific) at a price of 3¢/lb.

APPENDIX D

REINFORCEMENT

2

R-001-Utilization of Plant-fiber Residues-C.S. Walters (Prof)
University of Illinois, College of Agriculture

There was only a minimum amount of information provided. Furnishes were made from sawdust, shavings, bark, and corn cobs. They state that commercially acceptable wall board was made from all composites but bark. Bark board was improved by utilizing wood waste facing. The board is not a primary structure.

MSC could with more information, possibly combine the furnish with a resin and some longer fibers and produce a structural composite.

3

R-002-Development of Cabron Products from Lignin (Paper Mill)
Wastes - R.J. Lockhart, S.A. Bortz, Proceedings of the
Third Mineral Waste Symposium

The material could be used as a reinforcing fiber. The process is very much in a research concept approach and is premature for this program.

R-003-Solid Waste-Plastic Composites: Physical Properties and
Feasibility for Production-L.T. Fan, D.G. Retzloff, W.O.
Vanderpool, Environmental Science & Technology-Vol 6, No 13,
December 1972, page 1085-1091

Computer printout paper and card, newsprint, sawdust,
bagasse, wheat straw, dried sewage, sewage sludge, cotton
cloth, clothes lint and hair were coated with methyl
methacrylate and the mix irradiated. The results were
some good materials.

MSC should review the process and consider the compressed
paper as a major reinforcement with wood a secondary candidate.

51
R-004-How Sewage & Solid Wastes can be Recycled into Useful
Products-Research Trends, Autumn 1971, pg. 54-58

This article presents a system of processing both liquid and dry wastes. Experiments showed that sintered material can be made from sewage sludge.

This has long range potential for reinforcement but very little immediate application.

R-004A-Houses Built From Rice Waste- Science Journal

LONDON: Some time in 1968 the first building to be constructed from bricks with rice husks as the main constituent will be erected in Britain. Behind this development is the Tropical Products Institute, London, which, for the past few years, has been concentrating increasingly on projects to utilize waste products of tropical agriculture.

Developing bricks from the husks of rice seemed attractive in this context but, until recently, the project suffered from two drawbacks: the bricks could not be employed for load-bearing parts and they absorbed too much cement. This has now been overcome: the cement content has been radically reduced and it may now be possible to bring it down to perhaps half that of the original concept; moreover, hydraulic pressure instead of atmospheric pressure is now used to produce the bricks. They are now entirely suitable for load-bearing parts such as beams, lintels and doorframes. It is estimated that an outfit to produce these bricks would cost around £ 500. All that is required is a small hydraulic press, a dryer and the electricity necessary to run it.

R-005-Industrial Utilization of Solid Waste-Economic and
Engineering Analysis of a Straw-Particle Board Plant-
R.R. Groner, J.F. Barbour, Dept. of Agricultural Chemistry
Oregon State University

This study utilized straw for the production of particle boards. An economic analysis of facility and product costs are presented. Small plants spread over an area are proposed to assist in the collection and processing of straw.

Straw has a potential as a reinforcement for MSC.

R-006-Converting Bark into Opportunities-A.C. Van Vliet-
Oregon State University, Dept of Forest Products

The attached Table presents an estimate of bark production in three western states. Transportation is a cost item as well as the % moisture. Dry deck timber runs about 24% and ponded timber 82%. The bark from dry deck timber has grime and dirt in it. The bark from ponded timber is cleaner. Components have been made from molded bark without binder.

Bark is both a potential reinforcement and a matrix for MSC.

as much bark as is unused.

Table 1. How Much Bark?

UNITED STATES			
Estimated 14 million tons (ovendry)			
Other estimates: 7.2-20 million tons			
WEST COAST			
State	Produced	Unused	
	Dry tons	Dry tons	%
California (1968)	1,526,000	1,053,000	69
Washington (1968)	1,326,000	429,000	32
Oregon (1967)	3,200,000	1,500,000	47
All three	6,052,000	2,982,000	49

9
R-007-Bark as an Ingredient in Molded Items, Particle Boards,
Adhesive and other Products-R.A. Currier, W.F. Lehmann,
Dept of Forest Products, Oregon State University

Bark has been used as a reinforcement for both thermosetting and thermoplastic molding resins. Bark can also be used as a filler to extend resins. Bark is also capable of producing particle board.

MSC should consider bark as a reinforcement and a filler.

10

R-008-An Assessment of Current Bark Utilization Opportunities-
R.A. Currier, Dept of Forest Products, Oregon State Univ.

Bark is a residue material that can be used for fiber, filler, or matrix. OSU is conducting studies on the self bonding effect of bark and various molding compounds. Addition of more than 25% to particle board furnisher reduces strength.

R-009-Bagasse Structural Board-Our Hope?- M.F. Gloria-
Central Azucarera de Bair, Sugarland, June-July, 1972

Bagasse forms 45-50% of the dry content of sugar cane.
It can be mixed with a resin binder to form a strong structural
product or it can be molded by itself to form a particle board.
The breakdown of bagasse is -

Moisture	49%
Fibrous Component	45% and
Soluable Components	6%.

The fibrous components consist of

Fibers	63.4%
Pith	21.6%
Dirt & Dust	10%

This has potential as a reinforcement.

Plastic scrap aids labour shortage in S.A. building trade

Pollution created by disposed plastic products, the general labour shortage in building and a poodle dog have been main contributions to the invention of a low costing building panel by a 65-year-old Cape Town shipbroker, Sam Swindell.

Although an application for a South African patent has already been accepted, Mr Swindell told PP&R that the panel — which constitutes a cement base with chemically treated, chopped waste plastic as an aggregate — needs to be perfected. Once satisfied, Mr Swindell will go ahead with his ultimate bulk production plans, probably towards the end of this year.



On the right chopped plastic chips and on the left a block made from the compound.

"Stark realisation of the brewing plastic pollution problem was literally brought home to me by my poodle dog during last summer," said Mr Swindell. "Living near the beach in Sea Point, the dog had the habit of collecting any disposed item he could find and bringing it to me. His favourite article proved to be the common plastic fruit juice bottle, and the amount he used to collect in one walking session became almost outrageous!

"Around about the same time I happened to pick up a newspaper carrying an article describing the frightening plastic pollution problems in the United States. There were also pictures conveying this problem in our own Durban."

These observations led the shipbroker to investigate plastic wastage and disposal statistics.

"When I discovered that an estimated 15-million plastic bottles alone are manufactured daily in South Africa, and that one manufacturing company was prepared to give me 20 tons of wastage at the moment of asking, I decided at first to develop a brick, using chopped plastic as aggregate."

But this decision was short lived as, besides the expense involved, Mr Swindell foresaw its impracticability with regards to the current labour shortage in the building industry.

"The panel idea proved to be the most sensible. I have since calculated that an average three-bedroomed house would require under 50 panels, each measuring 3 m x 1 m x 10 cm thick, and at approximately R10 a panel, material costs would be at a

minimum as opposed to the conventional brick house."

Using plastic waste as a brick aggregate is being done elsewhere in the world, but Mr Swindell's panel, for which he has applied for world patents, is believed to be the only one of its kind.

Each unit embodies a steel rod, which has a thread at one end and a clip arrangement at the other. Once a panel is placed in position, the adjoining rods are clipped together and the exposed threaded end is then bolted down for maximum security.

One of the features of the material, according to its inventor, is that it will not chip or crack: "You can drill into it, plane it, hammer nails into it, in fact penetrate it by any conventional method, and it won't give way. Its durability is further enhanced by the fact that the average life of cement is 60 years, and plastic, of course, is indestructible."

The waste plastic is strengthened and depolarised once by chopped chemicals to eliminate such characteristics as static electricity, etc.

Mr Swindell has also developed a ceiling panel by the same process, but using a lighter cement.

Paint goes underground in aerosol cans

A non-flammable aerosol paint for marking strategic working areas on mining stopes has been developed by Sanwell Laboratories (Pty) Ltd of Johannesburg. Sanwell are already selling this product in large quantities to mining houses on the Reef.

By putting stoping paint in an aerosol can, Sanwell has helped simplify operations for mine workers throughout the country.

"Instead of carrying a brush and can around, the mine worker now merely keeps the aerosol container in his pocket," said Sanwell managing director, Norman Sanan.

Designated MK 401, the stoping paint is available in red, yellow, blue, white and green.

It took Sanwell a full year to develop the paint and according to Mr Sanan its non-flammability char-



Mr Sanan

acteristic is its chief attraction for underground use. This stoping paint is the only actual product made by Sanwell. Basically, they are contract aerosol loaders and a large portion of their business involves filling aerosol cans for paint manufacturers.

Mr Sanan believes the potential for putting paint into aerosol containers has by no means been fully exploited in South Africa.

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30 years. Page says this investment level would be sustained by means of eight new plants in Athabasca. He visualized a new 125,000 bbl/day plant coming on-stream, one every three years, after 1978. Page estimates the sands could yield 2 million bbl/day of hydrocarbons for the next 200 years (GCOS estimates it at 450 years).

Petroleum shortages exist in U.S.A., Japan, and Europe. With demand rising crude oil producers are asking and getting higher prices for conventional oil. Alberta producers, for example, recently jumped petroleum to \$3.10 to \$3.20 per bbl (f.o.b. Edmonton), and are giving notice that conventional oil could hit \$3.35 - 3.50/bbl within a year. Since GCOS has been doing its book-keeping at a price of \$3.00/bbl, more or less, then syn-crude certainly will be competitive, and profitable, in the near future. Some signs of renewed interest in syn-crude have already appeared. Shell Canada announced that it is resuming its research into *in-situ* recovery of bitumen (Shell has leases on oil sands well below the surface). Shell may build a \$30-million pilot facility near Peace River, Alta, this year. By 1983, Shell could be operating a full-scale complex. Recently, Alberta's oil circles have mentioned new contenders for Athabasca complexes. They include a Home Oil/Consumers Gas syndicate, a US group led by Shaheen of New York, and a consortium of Japanese companies.

Straw and other waste cellulose could become valuable raw materials, according to work done at Oregon State University. Researcher R. Groner says he produced both particle-board and slow-release fertilizers from cellulosic wastes. For board, he pulverized straw and municipal waste, dried the "meal", and then converted it to board. He used an unspecified resin and catalyst to speed the curing of the board at moderate pressures and temperatures. The resultant particle-board exhibited many useful properties. He estimates a \$410,000 plant could produce 15-16 mm. board at cost below that of interior plywood (14 c/sq ft for board, 18 c/sq ft for plywood). Groner's team also converted straw into fertilizer. Urea and phosphoric acid will react with straw to form a useful fertilizer. But when copper chloride catalyzes the reaction, the resultant fertilizer behaves both as a soil conditioner and a slow-release fertilizer. The Oregon State team also found that they could convert straw and waste paper into a plastic material with many of the characteristics of cellulose acetate.

See
R-005

Tomorrow's 'Trees'?

Paper Concerns Eye the Fibrous Kenaf Plant As Future Substitute for Scarce Wood Pulp

By PAMELA G. HOLLIE

Staff Reporter of THE WALL STREET JOURNAL

The 10-foot-tall kenaf plant doesn't provide shade or housing for squirrels, nor is it strong enough to support a tree house. But in at least one respect, the kenaf plant may someday replace the tree. Kenaf (pronounced kuh-NEF) could be the answer to the paper industry's search for fiber sources.

A type of hibiscus that looks a lot like the marijuana plant, kenaf's main attribute is a fiber yield unsurpassed by any tree yet developed. It produces five to seven times more pulp per acre than the pine tree, for example. And it grows to maturity in only 120 days, compared to 20 years for most trees.

At a time when future wood-fiber shortages are being projected, these qualities make kenaf increasingly attractive to the pulp and paper industry. "The world's pulp and paper industry is becoming more and more concerned about its future sources of fibrous raw material," says Joseph E. Atchison, whose New York consulting firm has evaluated nonwood plant fibers for the pulp and paper industry. "There is no question that nonwood fibers will play an increasing role in satisfying fiber requirements," he says.

A Scarcity of Trees

The search for nonwood fibers stems from the fact that trees just don't grow fast enough. In fact, there probably aren't enough trees to meet the nation's fiber needs much beyond the 1990s, some paper experts say.

Paper consumption, which is now 440 pounds per person a year, is expected to climb to more than 1,000 pounds per person a year by the year 2000. U.S. paper and paperboard production was 61.9 million tons last year, more than 3 million tons short of demand.

"It's also possible that trees could become uneconomical (for papermaking) in coming years, as demand for high-cost wood products takes priority," says C. E. MacDonald, International Paper Co.'s director of allied operations. This has already begun to happen; only wood scraps are made into paper in order to conserve more of the tree for paneling, furniture and housing products. "Trees are too valuable to grow just for paper," Mr. MacDonald says.

Though fiber shortages are a new worry for the U.S., many sparsely forested countries have always faced this problem. In Europe and Asia millions of tons of paper are made from fibers like bamboo, reeds, rags, bagasse (sugar cane) and straw from wheat, rice, oats and barley. Papyrus, possibly the original paper fiber, is still being used in some countries.

Rigid Specifications

The U.S., too, has a number of varieties of nonwood fibers available. Some 70.8 million tons are produced each year, mostly as a byproduct of the harvest of other crops. But wood is much more economical for papermaking than these fibers, and only about one million tons are turned into paper each year.

Although paper can be made from almost any fiber, manufacturers have a long list of criteria for a commercially suitable material. The industry wants a long, strong fiber that can be easily extracted for pulping. It must be versatile and easily handled. And it should be a fast-growing crop that can be easily harvested several times a year. To conserve land and ensure continuous operations, it should have large yields per acre.

With these specifications in mind, scientists have singled out kenaf as a likely possibility to replace wood pulp for papermaking. It was selected after a long investigation by the U.S. Department of Agriculture that began in 1957. The agency started out looking for a good cash crop for farmers and, recognizing the possibility of future fiber shortages, began tests to determine which plant would best fit the paper industry's requirements.

Corn, Parsley and Honeysuckle

In the course of their investigation, the researchers tested some 6,000 seeds from 3,500 species of fiber plants. Of this group, about 860 were chosen for careful evaluation. Cornstalks, milkweed, honeysuckle and certain types of parsley all showed promise, but were rejected for a variety of reasons. Hemp had strong potential, except that its cultivation is rigidly controlled to prevent the illegal use of its dried leaves as marijuana. Zinnias and sunflowers were deemed too difficult to harvest.

In 1960, kenaf was selected as the best possible candidate—for its strength, harvesting potential, similarity to wood fiber and its pulping and mixing characteristics. "It makes good paper," says Thomas Clark, a USDA kenaf researcher. Mr. Clark, who oversees an experimental kenaf crop at the agency's research laboratory in Peoria, Ill., says the fiber can be made into anything from newsprint to boxes.

But the widespread use of kenaf may still be a long way off, for the paper industry hasn't yet given up on trees. It is devoting huge amounts of time and money to a research effort designed to forestall the wood-fiber shortage.

Manufacturers are turning their attention to trees once considered unsuitable for papermaking; tropical hardwoods such as mahogany are being used for the first time, for example. The increased use of Southern pine trees has relocated the paper indus-

try's operations from the forests of the North to the plantations of the South. New scientific developments now make it possible for the eucalyptus tree to grow to 85 feet in five years or less under optimal conditions. And International Paper Co. has developed fast-growing, sturdy "supertrees." One was nicknamed "Marilyn Monroe" because it was "gorgeous" and had great limbs.

Getting the Bugs Out

Despite kenaf's high yield and fast growth, it has some drawbacks that may slow its acceptance by paper manufacturers. Like many crops, kenaf must be rotated every few years. Its seedlings rot when exposed to too much water and must be planted in raised beds. The plant would also require an entirely new system of land management. "Paper companies would have to become farmers," says one paper company executive.

The most troublesome problem that must be ironed out before kenaf paper becomes a reality is the root-knot nematode. This nearly microscopic worm burrows into the roots of the plant and saps its growth potential until it wilts. "Unless the bugs are out of it, kenaf will never be economical enough to use," says one paper-company executive.

Though many papermakers share his skepticism about the chances of overcoming this problem, USDA plant geneticist Charles Adamson is more optimistic. He has been trying to develop a nematode-resistant kenaf plant for five years at the agency's Plant Introduction Station in Savannah, Ga. Eventually, he believes, scientists will lick the bug problem.

While kenaf won't be used for tomorrow's newspaper, "it could become a useful source of paper production in the future," according to a spokesman for Weyerhaeuser Co., the timber-products concern. "Kenaf is an excellent fiber," he adds. Gordon B. Killinger, an agronomist at the University of Florida in Gainesville is more emphatic: "Kenaf could be the biggest thing since we learned how to make paper from pine trees back in 1928."

15

R-012-Possible Uses for Waste Rice Hulls in Building Materials
and Other Products-J.H. Hough, H.T. Barr, Bulletin No. 507
Agricultural Experiment Station, Louisiana State University
and A & M College

Rice hulls have been used as a reinforcement for adobe blocks, slump brick, and concrete. The ground hulls and ash have been used as filler for resins. The high silica content of the hulls are hard on machinery.

Rice hulls can also be used to manufacture furfural for use as a resin.

They can also be used for insulation.

The availability and composition of rice hulls and ash are presented below.

		Rice	Rice Hulls	Ash
Approximate Analysis of Rice Hulls (All varieties)				
Moisture	8.49% to 11.00%	Arkansas	744,440 tons	126,555 tons
Ash	15.68% to 18.59%	California	529,495 tons	90,014 tons
Ash (Insoluble in 10% HCl)	14.50% to 17.52%	Louisiana	719,432 tons	122,303 tons
Crude protein	2.94% to 3.62%	Mississippi	142,547 tons	24,233 tons
Ether soluble extract	0.82% to 1.20%	Texas	806,582 tons	137,119 tons
Crude fiber	39.05% to 42.90%	TOTAL	2,942,496 tons	500,224 tons
Nitrogen free extract	24.70% to 29.38%			100,045 tons
Typical Chemical Analysis of Rice Hull Ash				
Silica (SiO ₂)	94.50%			
Calcium oxide (CaO)	0.25%			
Magnesium oxide (MgO)	0.25%			
Potassium oxide (K ₂ O)	1.10%			
Sodium oxide (Na ₂ O)	0.78%			
Phosphoric oxide (P ₂ O ₅)	0.53%			
Sulphates (SO ₃)	1.13%			
Aluminum, manganese, ferric oxides (Al, Fe, Mn)	Traces			

16

R-013-Expedient Reinforcement for Concrete for Use in Southeast
Asia-F.B. Cox, H.G. Geymayer, Tech. Report C-69-3#1
Corp of Engineers, Vicksburg, Mississippi

Bamboo can be used as a reinforcing fiber as it has a tensile strength of approximately 50,000 psi and a modulus of 2.9×10^6 psi. There are problems with volume changes due to moisture variation, low interfacial bond strength and possible decay.

The limited availability rules out its use in the United States.

17

R-014-Expedient Reinforcement for Concrete for Use in Southeast Asia
F.B. Cox, J.E. McDonald-Tech Report C-69-3 #3-Corps of
Engineers, Vicksburg, Mississippi

This report evaluated further the use of domestic bamboo which has lower strength than the Asiatic variety. The tensile strength varied from 13,450 psi to 29,640 psi and the modulus from 1.89×10^6 to 3.52×10^6 psi. The interface is a problem and is inverse to the fiber length. The tests show that bamboo strength is not related to harvest. Considerable data on bamboo reinforced concrete is presented and shows that long term loading has a detrimental effect on the bamboo.

The low strength, interface and limited availability makes it unattractive for the United States.

18
M-005

R-015-The Chemical Conversion of Solid Waste to Useful Products-
J.F. Barbour, R.R. Groner, Dept. of Agricultural Chemistry-
Oregon State University

All solid wastes contain a large percentage of cellulose. The cellulose can be reacted upon to produce particle board, fibers, and other chemicals. Under certain conditions the waste material such as straw can be partially reacted where the cellulose acts as the binder and the remaining particles the reinforcement.

Full reactions of straw, paper and other materials have been used to form cellulose acetate which is then passed through orifices to form fibers.

Important tables are presented. This has potential for both fiber and matrix.

Table II. B. 1. Composition of Typical Municipal Refuse as Reported by
Kaiser (13).

<u>Category</u>	<u>Weight Percent</u>	
Paper		53.46
Corrugated paper boxes	23.38	
Newspaper	9.40	
Magazine paper	6.80	
Brown paper	5.57	
Mail	2.75	
Paper food cartons	2.06	
Tissue paper	1.98	
Wax cartons	0.26	
Plastic coated paper	0.76	
Moisture		9.05
Garbage		8.40
Vegetable food wastes	2.29	
Citrus rinds & seeds	1.53	
Meat scraps, cooked	2.29	
Fried fats	2.29	
Glass, Ceramics, Ash		7.73
Vegetation		
Ripe tree leaves	2.29	
Flower garden plants	1.53	
Lawn grass green	1.53	
Evergreen	1.53	
Metals		6.85
Miscellaneous		7.62
Wood	2.29	
Plastics	0.76	
Rags	0.76	
Leather goods	0.38	
Rubber compositoon	0.38	
Paint and oils	0.76	
Vacuum cleaner catch	0.76	
Dirt	1.53	
Total		99.99

Table II. B. 4. Estimate of Industrial Waste Composition in Oregon

		Volume Percent							
	Paper Waste	Wood Waste	Metal Waste	Animal Waste	Textile Waste	Petro-Cheml	Fruit Vegtbl	Rubber Plastic	Sand, stn Glass, Ash
Meat Processing	97	3	>1					1	
Electric Machinery	97	1						3	1
Dairy Products	96	>1					3		>1
Misc. Food Processes	94	1							
Printing & Publication	94	4	1			>1			
Petroleum & Allied	92	5							3
Scientific Instrument	88	5	1		>1	>1		5	
Ordnance	85	11	1			2			
Non-Elec. Machinery	82	13	3					2	
Processed Foods	70	>1	5				23	2	
Apparel Products	69	1	1		28			1	
Rubber & Plastics	69	13	1		1	>1		16	1
Chemical & Allied	60	27	8			8			<1
Transportation	58	40	1		1			43	
Misc. Manufacturing	57								
Cannery & Frozen	56	3	2			>1	39	>1	<1
Textile Mills	54	2	1		42	>1		>1	<1
Furniture	52	39	4		3			1	11
Stone, Clay & Glass	44	40	5			>1		>1	
Seafood Processing	43	13	10	33				1	47
Fabricated Metals	43	43	14						<1
Primary Metals	30	7	15			>1			<1
Wood Products	27	65	6			1		1	2
Paper & Allied	25	4	1					3	
Leather Manufacture	14	2	4	72	>3				

Table II. B. 7. Composition of Cereal Straws

wt.%, dry basis

Component	Oat min. - max.	Rice min. - max.	Wheat min. - max.
Dry matter	83.9 - 95.2	88.8 - 93.4	82.8 - 99.1
Cellulose	40.1		35.3 - 63.9
Lignin	13.4 - 15.8		12.4 - 15.1
Pentosans		17.7	10.2 - 12.8
Crude protein	2.0 - 8.6	2.8 - 6.2	1.5 - 6.9
Crude fat	0.8 - 3.2	8.7 - 2.3	1.0 - 3.7
Crude fiber	33.3 - 54.0	27.6 - 38.3	36.4 - 51.5
Ash	4.9 - 12.9	14.0 - 20.1	3.5 - 11.1
Sulfur	0.20 - 0.27		0.13 - 0.29
Sodium	0.23 - 0.53	0.31	0.06 - 0.23
Chlorine	0.70 - 0.85		0.21 - 0.34
Calcium	0.13 - 0.40	0.15 - 0.38	0.10 - 0.42
Phosphorus	0.15 - 0.43	0.06 - 0.15	0.04 - 0.51
Potassium	0.20 - 2.41	1.10 - 1.51	0.12 - 1.95
Magnesium	0.16 - 1.48	0.07 - 0.18	0.05 - 0.70
Iron	0.018- 0.056		0.007- 0.017

Table II. B. 8. Composition of Grass Seed Straws

wt.%, dry basis

Component	Fine Chewings Fescue	Merion Bluegrass	Highland Bentgrass	Perennial Ryegrass	Annual Ryegrass
Crude protein	5.2	9.1	4.6	5.5	4.5
Crude fiber	45.1	36.6	39.4	41.2	40.2
Crude fat	1.8	2.1	1.9	1.8	1.4
Crude pectin	1.1	1.6	1.7	2.3	1.8
Ash	7.0	5.4	2.7	6.7	6.6
Total sugars	0.20	2.49	2.01	0.68	4.05
Reducing sugars	0.17	1.74	0.96	0.43	3.25
Pentosans	27.1	24.0	24.8	22.0	23.7
Lignin	10.2	8.7	9.0	8.8	8.6
Cellulose	45.2	41.6	44.2	42.3	42.3

Wood Scientists Make Boards From Plant Residues

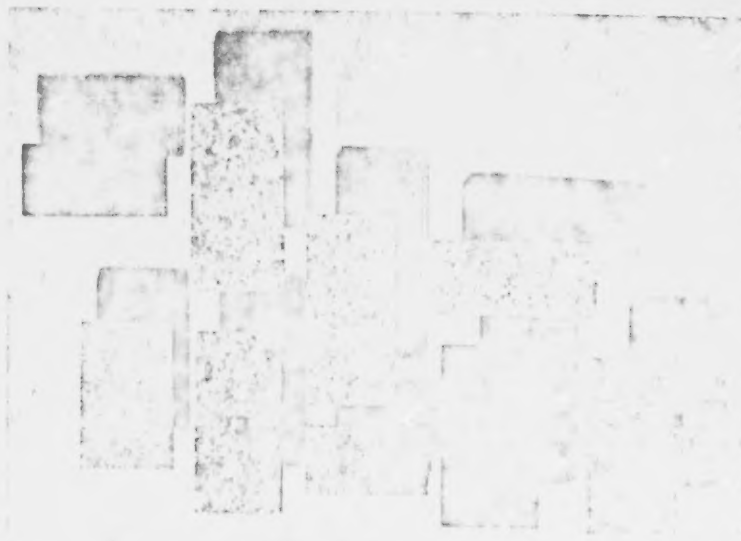
C. S. WALTERS

THE VOLUME of plant-fiber residues developed from farming, lumbering, and milling operations in Illinois must be tremendous. In the past the residues were burned, dumped, or left until they decayed. Some were applied to the soil, but the percentage used in this way was only a fraction of the total volume produced.

Anti-pollution legislation has created a new interest in finding uses for the residues. Burning them pollutes the air; dumping them into waterways is no longer an acceptable means of disposal. A pile of sawdust, corn-cobs, or sawmill slabs is unsightly and it occupies space. In addition to these residues, there is a large volume of wood in trees that has neither a pretty grain nor a desirable color, and some trees are too small or of too poor quality to be usable at present.

The Department of Forestry is studying ways of converting wood residues and substandard wood into usable products, thereby solving the disposal problem and at the same time developing a new source of income for the producers.

In exploratory tests, panel boards of good strength were made from sawdust, corn-cobs, cornstalks, corn



A variety of materials, including hardwood shavings, oak bark, walnut bark, hickory sawdust, cornstalks, and corn-cobs, were used to make these wood panel boards. (Dark rectangles in background are shadows, not panels.)

leaves, tree bark, wood chips, and mixtures of these residues. The test panels were too small for results to be conclusive, however, so a larger hot-press has recently been obtained for the study.

Various fiber residues will be mixed with glue and the mixture pressed into a sheet with the hot-press. The press will both compact the particles and cure the adhesive. Some boards will be light in weight for insulating walls and ceilings; others will be dense and strong for wall sheathing, cabinet parts, and table tops.

Bending strength, stiffness, water-absorption capacity, swelling, and

screw-holding ability of the panels will be measured. Different kinds and amounts of adhesive will be correlated with the stiffness and bending strength of the panel boards.

An attempt will be made to use the best properties of each material. For example, the way the fibers are oriented in a plant such as a cornstalk may give superior strength if the same orientation is used in a panel.

One of the objectives of the study will be to make the panel boards fire- and decay-resistant by treating them with chemicals.

C. S. Walters is Professor of Wood Technology and Utilization, Department of Forestry.

istics and structural capabilities specified by building codes and lending agencies. The trusses have to be stiff enough to prevent plaster and dry-wall finish materials from cracking, and strong enough to support various types of loads, such as snow on the roof and stored items in the attic.

The frames were loaded on a hydraulic test floor at the Small Homes Council. Simulated roof loads were applied along the top chords of the

frame through one set of hydraulic cylinders and the storage loads applied to the 8-foot central area with a second set of cylinders (Figs. 1 and 2).

Results of the actual full-scale tests were compared to the theoretical or computer analyses. Very close similarity was found in the deflection characteristics. Deflection of all frames was well within the limitations as required by the building codes.

After the deflection readings were taken, each frame was loaded until it failed. No failure occurred until the load was more than $2\frac{1}{2}$ times as great as the design load specified by most building codes and lending agencies.

Both storage frame designs and additional information are available from the Small Homes Council-Building Research Council, University of Illinois, 1 East St. Mary's Road, Champaign, Illinois 61820.

24

R-017-Specific Gravity, Bulk Density and Screen Analysis of
Midwestern Plant Fiber Residues-Poo Chow, C.S. Walters,
J.K. Guiher, Forest Products Journal Vol 23 No 2

Cellulose residue from forest and agronomic wastes are applicable as reinforcing fibers and have been used to make particle board. This study showed that unrefined densities do not necessarily relate to the refined furnisher. Materials evaluated are -

- Red Oak Bark
- White Oak Bark
- Walnut Bark
- Cottonwood Bark
- White Oak Chips (Cooperage Waste)
- Red Oak Sawdust
- Maple Trims and Shavings
- Corn Cobs
- Corn Stalks
- Sunflower Seed Coats
- Aspen Fiber
- Southern Pine Fiber

25

R-018-Ph Measurement for Pressure-Refined Plant-Fiber Residues-
Poo Chow, C.S. Walters, J.K. Guiher

The Ph of the fiber residue is important when combining with a matrix and filler for cure. All plant fibers studied in R-017 were acidic except pressure-defiberized maple shavings, cornstalks and unrefined cottonwood shavings.

26
R-019-New Uses Found for Discarded Christmas Trees - Poo Chow
Illinois Research, Summer 1973, Vol 15 No 3

Christmas trees (Scotch Pine) were cut into chips and made into particle board. The strength was 960 psi and the modulus of elasticity was 230,000 psi.

27

R-020-Utilization of White Fir Bark in Particle Board-
A.B. Anderson, A. Wong, K. Wu, Forest Products
Journal Vol 24 No 1

Particle boards were made from white fir bark by adding paraformaldehyde. This reacts in situ with polyphenolic compounds present in bark and forms a water resistant bond. The strength level is low.

28

R-021-Molding Characteristics of Some Mixtures of Douglas-
Fir Bark and Phenolic Resin-D.J. Miller, Forest Products
Journal Vol 22 No 9

Molded cups were made from ground Douglas-fir bark and small amounts of dry phenol-formaldehyde resin. The material blistered in many cases. This could have been caused by entrapped air and outgassing of the phenolic resin. Variation of resin content, cure and mold opening temperatures were evaluated.

29

R-022-Bureau of Mines Research and Accomplishments in Utilization
of Solid Waste-F.J. Cservenyak, C.B. Kenahan, I.C. 8460

The experimental work has demonstrated an ability to make concrete blocks from waste glass and copper tailings. Also mineral wood has been produced from waste glass. Problems are associated with the cost of classifying and reclaiming waste.

30

R-024-Resource Recovery from Raw Urban Refuse-P.M. Sullivan,
M.H. Stranczyk, M.J. Spendlove, R.I. 7760-Dept of Interior

This is a further detail of refuse separation and cost.
If incorporated by cities, this could be a source of reinforcement supply in the future.

51

R-023-Cost Evaluation of a Metal and Mineral Recovery Process
for Treating Municipal Incinerator Residues-J.J. Henn,
F.A. Peters I.C. 8533-Department of Interior

The methods and costs for separating and recovering waste are presented. The Bureau feels that the system is technically and economically feasible.

This is a source for reinforcement in the future.

32

R-025-Bureau of Mines Research Programs on Recycling and
Disposal of Mineral, Metal, and Energy Based Solid Waste,
C.B. Kenahan, E.P. Flint, I.C. 8529, Dept of Interior

This summarizes two programs sponsored for developing
concrete bricks from waste and presents an extensive
bibliography. This is a potential supply of reinforcement.

33
R-026-Bureau of Mines Research Programs on Recycling and
Disposal of Mineral, Metal, and Energy Based Wastes-
C.B. Kenahan, R.S. Kaplan, etal., IC 8595, Dept of Interior

This is an update of R-025 (IC 8529)

34

R-027-Cultural and Harvesting Methods for Kenaf Production
Research Report No. 113, Dept of Agriculture

This is a study on the potential production of Kenaf in the United States. Kenaf has long fibers and is imminently suitable as a reinforcement.

R-028-A Search for New Fiber Crops-T.F. Clark, etal The Journal
of Technical Association of the Pulp and Paper Industry,
Vol 50, No 11, November 1967

This discusses the potential crop yield. The kenaf is
a cash crop and not waste. However, it would be an excellent
fiber.

APPENDIX E

F-001-Ash Utilization-Views on a Growth Industry- by J.N. Covey,
J.H. Farber-Proceedings of the Third Mineral Waste Symposium

This primarily summarizes the use of ash in concrete etc.
This is summarized in Table I. The projection of ash availability
is in Figure 1. Ash would be directly applicable to MSC as
a filler.

2

TABLE I
Ash Collection & Utilization — 1970

	Fly Ash Tons	Bottom Ash Tons	Boiler Slag (If separated from Bottom Ash) Tons
1. TOTAL ASH COLLECTED	<u>26,538,019</u>	<u>9,890,951</u>	<u>2,801,475</u>
2. ASH UTILIZED			
a. Mixed with cement clinker or cement (pozzolan cement)	12,293	—	—
b. Mixed with raw material before forming cement clinker	146,191	5,850	—
c. Partial replacement of cement in:			
1. Concrete products	168,129	1,900	3,368
2. Structural concrete	238,766	—	—
3. Dams and other mass concrete	129,415	—	—
d. Stabilizer for road bases, parking areas, etc.	111,309	18,125	70,309
e. Lightweight aggregate	207,019	50,522	—
f. Fill material for roads, construction sites, etc.	320,304	774,828	497,876
g. Filler in asphalt mix	131,270	—	27,077
h. Miscellaneous	167,302	613,829	479,576
TOTAL ITEM #2	<u>1,631,998</u>	<u>1,465,054</u>	<u>1,078,206</u>
3. Ash removed from plant sites at no cost to utility but not covered in categories listed under "Ash Utilization"	526,347	377,898	16,156
TOTAL UTILIZED Items #2 & #3	<u>2,158,345</u>	<u>1,842,952</u>	<u>1,094,362</u>

Source: Edison Electric Institute

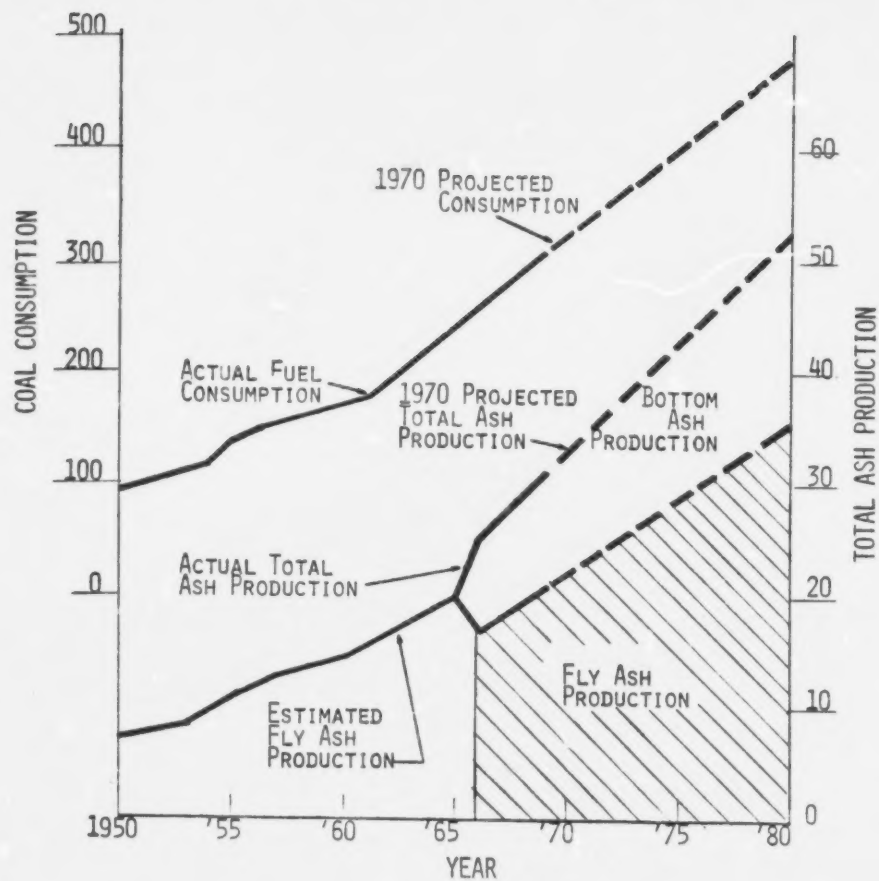


FIGURE 1. COAL CONSUMPTION AND TOTAL ASH PRODUCTION BY U. S. ELECTRIC UTILITIES (IN MILLIONS OF TONS)

4

F-002-Recycling Container Glass-J.H. Abrahams Jr.-Proceedings
of the Third Mineral Waste Symposium

This material could be used as a filler and possibly a matrix. The following excerpt relates this information.

Also, there are some recent studies which indicate that ground glass can act as a synthetic pozzolan. Pozzolans are defined as a silicious and aluminous substance that reacts chemically with calcium hydroxide at ordinary temperatures in the presence of moisture to form a cement-like material. As such, ground glass could potentially replace cement in concrete, and improve the properties and workability of the concrete. About 80 million tons of cement are used annually. It is anticipated that some 20 to 40 percent of the cement will be replaced by pozzolans, which presently consist of natural minerals and fly ash.

5

F-003-Utilization of Florida Phosphate Slimes-S. Vasan-
Proceedings of Third Mineral Waste Conference

The system as it presently is available would have too much moisture for use as a filler. The economics are questionable.

6

F-004-Application of Silicate Waste from Paper Processing-
N.L. Hecht-5-9-74 Proceedings of the Third Mineral
Waste Symposium

Silicate can be used as a filler but this source is
local and of a questionable production ability.

F-005-Recovery of Values from Shredded Urban Refuse-K.C. Dean,
C.J. Chindgren, L. Peterson-Proceedings of the Third
Mineral Waste Symposium

The material is at this time of limited availability.
The article defines the system for recovery and does provide
waste breakdown, Tables 1 and 2.

TABLE 1. - Characterization of Madison
refuse samples

	Analysis, percent
Metal:	
Ferrous.....	5.7
Nonferrous.....	.3
Moisture ¹ /.....	12.4
Nonmetal:	
Paper.....	41.0
Cardboard.....	15.3
Cloth and leather.....	4.4
Plastic.....	2.9
Wood and plants.....	1.5
Rubber.....	.6
Dirt and glass.....	15.9

¹/ Varied between 5 and 30 percent on different
lots.

TABLE 2. - Screen-sized distribution of
Madison refuse

	Component, weight-percent			
	-6 -1 inch	-1 inch +4 mesh	-4 mesh	Total
Metal:				
Ferrous.....	4.7	1.8	-	6.5
Nonferrous.....	.1	.2	-	.3
Total.....	4.8	2.0	-	6.8
Nonmetal:				
Paper.....	3.2	41.5	2.1	46.8
Cardboard.....	11.2	5.8	.5	17.5
Cloth and leather.....	4.8	.2	-	5.0
Plastic.....	2.5	.8	-	3.3
Wood.....	.5	1.1	.1	1.7
Rubber.....	.7	-	-	.7
Dirt and glass.....	-	2.3	15.9	18.2
Total.....	22.9	51.7	18.6	93.2

8

F-006-Extrusion-A Means of Recycling Waste Plastic and Glass-
R.L. Davis, P.G. Hansen, S.C. Kekar

The scrap is an adequate filler but of questionable supply at this time.

The results presented in this paper provide evidence that waste materials, specifically glass and plastics, can be converted into usable structural elements - rods, bricks, and blocks. Billets composed of glass particles and a polymer matrix have been formed and extruded through dies by hydrostatic and conventional extrusion to form cylindrical and rectangular shaped products. The extrusion pressure and temperature have been varied to determine the preferred conditions for forming a product from various combinations of glass and plastic particles. These extrusion formed products have been tested, and the preliminary results indicate that the strengths are better than that of concrete.

Current work on this project is intended to reveal more information on the coupled effects of glass particle size, polymer composition, and extrusion parameters (reduction-in-area, pressure and temperature).

9
F-007,

F-008-Refuse Glass Aggregate in Portland Cement Concrete
Waste Glass as an Ingredient in Lightweight Concrete-
Proceedings of the Third Mineral Waste Conference

Glass can be used as a filler but its availability and
economics are questionable.

10

F-009-Characterization, Benefication and Utilization of
Municipal Incinerator Fly Ash

This is a good filler candidate.

Results of characterization and utilization studies of municipal incinerator flyash are described. Chemical and physical characterization tests include visual analysis, elemental composition, specific gravity separations, and screen separations. Potential large tonnage uses examined involve the bench scale production of lightweight aggregate and brick. Other utilization areas examined include the production of aerated concrete and castable ceramic.

F-010-Feasibility of Utilizing Waste Glass as a Component for
Lightweight Structural Building Products-R.O. Shotts,
R.M. Cox-U.S. Bureau of Mines Contract G0100S9 (SWD-28)
College of Engineering, University of Alabama BER Report 140-119

This describes the potential processing of glass from
city wastes. The reported directed is research to concrete.
However, MSC could use ground glass as filler. The availability
and economics are questionable.

12

F-011-Recovering Plastics from Urban Refuse by Electrodynamics
Techniques-M.R. Grubbs, K.H. Iuey-College Park Metallurgy,
College Park Maryland, Research Center, Bureau of Mines
Solid Waste Research Program TPR 63, December 1972

This report shows that an electrodynamic separation technique is feasible for separating thermo plastic from a mix of plastic paper recovered from refuse.

MSC could use the ground up plastic as a filler. At this time there is no known source of active supply.

APPENDIX F

Department of
Forest Products



Corvallis, Oregon 97331

March 18, 1974

Mr. Bud L. Duft
President
Material Systems Corporation
751 Citracado Parkway
Escondido, CA 92025

F-861

Dear Mr. Duft:

I have your letter of March 5 regarding candidate waste-derived materials for fiber, filler or binder in structural wall panels.

This laboratory has a strong interest in utilization of bark waste from our forest products industries; our on-going program includes supportive research in that area. Usefulness of bark in your panel product would likely be more as filler than as fiber or a binder. Bark fiber has been used to reinforce plastic moldings, but the short fiber length (about 1 mm) would seem inadequate for your product. Bark also has some self-bonding ability under heat and pressure, primarily resulting from thermoplastic flow and physical consolidation of corky tissue in the bark, but I wouldn't expect it to serve as a strong binder. Possibilities for bark as a filler in your panel seem more likely; it has been possible to add 25% of Douglas fir or hemlock bark into the core zone of particleboard and still have acceptable board strength.

Quantities and availability of bark should be adequate. Oregon alone generates an estimated 1.3 million dry tons of unused bark annually.

Thanks for your invitation to visit your plant in Escondido. Because I cannot foresee a visit now, would you please send me a sample of your product?

Sincerely,

A handwritten signature in cursive script that reads "Don Miller".

D. J. Miller
Assistant Professor

klm

141

**F-013-Possible Uses for Waste Rice Hulls in Building Materials
and Other Products-J.H. Hough, H.T. Barr-Bulletin No. 507-
Agricultural Experiment Station-Louisiana State University
and A & M College**

Rice hulls have been used as a reinforcement for adobe blocks, slump brick, and concrete. The ground hulls and ash have been used as filler for resins. The high silica content of the hulls are hard on machinery.

Rice hulls can also be used to manufacture furfural for use as a resin.

They can also be used for insulation.

The availability and composition of rice hulls and ash are presented below.

		Rice	Rice Hulls	Ash
Arkansas		744,440 tons	126,555 tons	25,311 tons
California		529,495 tons	90,014 tons	18,003 tons
Louisiana		719,432 tons	122,303 tons	24,460 tons
Mississippi		142,547 tons	24,233 tons	4,847 tons
Texas		806,582 tons	137,119 tons	27,424 tons
TOTAL		2,942,496 tons	500,224 tons	100,045 tons

Approximate Analysis of Rice Hulls (All varieties)	
Moisture	8.49% to 11.00%
Ash	15.68% to 18.59%
Ash (Insoluble in 10% HCl)	14.50% to 17.52%
Crude protein	2.94% to 3.62%
Ether soluble extract	0.82% to 1.20%
Crude fiber	39.05% to 42.90%
Nitrogen free extract	24.70% to 29.38%
Typical Chemical Analysis of Rice Hull Ash	
Silica (SiO ₂)	94.50%
Calcium oxide (CaO)	0.25%
Magnesium oxide (MgO)	0.23%
Potassium oxide (K ₂ O)	1.10%
Sodium oxide (Na ₂ O)	0.78%
Phosphoric oxide (P ₂ O ₅)	0.53%
Sulphates (SO ₃)	1.13%
Aluminum, manganese, ferric oxides (Al, Fe, Mn)	Traces

15
F-014-Utilization of High-Pressure Forming for Converting Waste
Glass into Useable Structural Materials- P.G. Hansen,
R.L. Davis-Dept of Engineering Mechanical, University
of Missouri, Rolla-Contract GO 100158 (SWD-27) U.S.
Bureau of Mines

This study crushed waste glass and mixed it with waste polyethylene and molded small parts with high hydrastatic extrusion. The resulting material had properties (4000 psi) adequate for building structures. However, the process appears costly.

Potential for MSC would be glass or plastic particles for filler.

F-015-Economics of Recycling Metals and Minerals from Urban
Refuse-P.M. Sullivan, M.H. Stanczyk, Bureau of Mines
Solid Waste Research Program, Tech Progress Report 33,
April 1971

This presents a possible source in the future for glass
and clay filler. The economics are presented for the material
recovery. The data has no effect on this present study.

17

F-016-Utilization of Mining and Mill Wastes-Bureau of Mines-
Contract No. H0190397 - IITRI Project No. G6027

Taconite tailings from the Mesabi Range in Minnesota was utilized to produce foamed bricks. These were mixed with bentonite, fly ash, and hydrated ironoxide mineral. The material was foamed and sentered to create foamed bricks in the 25-55 lb/ft³ range. The strength 50-900 psi is rather low.

MSC could consider taconite as a filler as well as fly ash.

F-017-Wastes from Processing of Aluminum Ores-A.G. Pincus
IITRI, First Mineral Waste Utilization Symposium

Red mud from bauxite processing has a potential as a filler. It is limited to certain areas of Texas, Arkansas, Louisiana, and Alabama. The generated amount is relatively small compared to other wastes as shown below. Its strength to weight ratio compares well as a foamed brick with other materials. See attached data.

17

Table I
PRODUCTION OF ALUMINA IN 1963 BY ORIGIN AND PLANT

Bauxite Long tons x 10 ³ dry basis	Domestic	British Guiana	Dominican Republic	Haiti	Jamaica	Suriname	Other
	Arkansas 1478 Ala. & Ga. 47	335	729	396	5,239	2,518	21
Total 10,695	1525						

Alumina Capacities Long tons x 10 ³	Sherwin, Texas	Hurricane Creek, Ark.	Bauxite, Ark.	Pt. Com- fort, Texas	Mobile, Ala.	Burnside, La.	Baton Rouge, La.	Gra- mercy, La.
Total 5,340	876	803	420	750	865	345	850	430

Table II
COMPARISON OF MINERAL WASTE OUTPUTS

	Approx. Tons/Year
Aluminum	
Red Muds	5 to 10 million
Brown muds	1/2 "
Storage estimated	100 " tons
Copper	
Utah Mine	30 million
Storage about +10 ⁹ tons	(57 years of operation)
Total U.S.	155,000,000 (1964)
Iron	
Taconite tailings	100 million
Total wastes from Taconites	230 "
Phosphate	
Florida and Tennessee slimes	20 million
Storage estimated about	1000 " tons

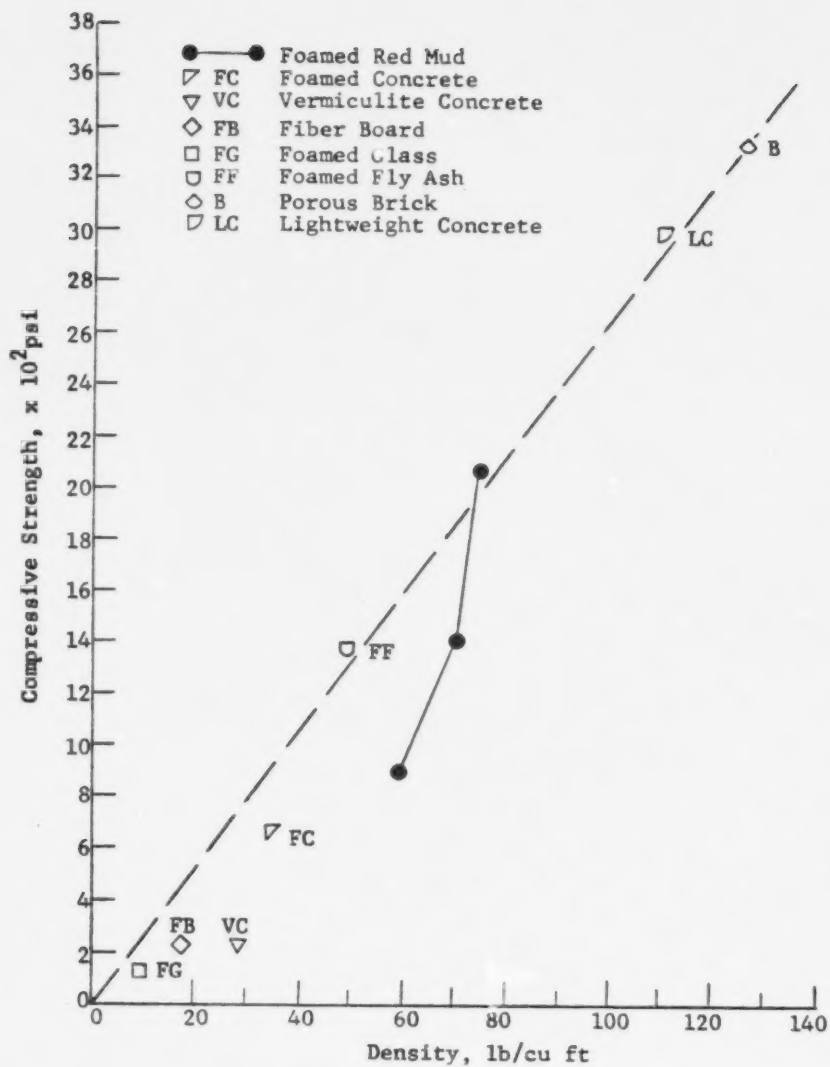


Fig. 2 - STRENGTH-DENSITY PROPERTIES OF FOAMED RED MUDS AND COMPETITIVE MATERIALS

F-018-Phosphate Wastes-J.L. Cox, International Minerals and
Chemical Corporation-First Mineral Waste Utilization
Symposium

Phosphate slimes are a local Florida problem and could have potential as a filler. However the processing is a major problem.

22

F-019-Coal Wastes-G.D. Sullivan, American Mining Congress,
First Mineral Waste Utilization Symposium

Coals refuse has a potential for producing alumina,
an excellent filler. However, no production is now available.

F-020-Utilization of Foundry Waste By-Products-P.R. Gouivens-
First Mineral Waste Utilization Symposium

Dusts from arc furnaces and sand reclaimer operations were evaluated as a filler for epoxy. They appeared to work well. Collection of these materials could be a problem for large quantity production.

F-021-Fly Ash Utilization-Problem and Prospects-J.H. Faber,
Bureau of Mines, First Mineral Waste Utilization Symposium

Fly ash offers a considerable potential for filler. The material is collectable, produced in large quantities both in the United States and internationally. The distribution is distributed over the country. (See Attachments)

TABLE 2. - Production and utilization of ash in 1965
(includes fly ash, hearth ash, and molten ash)

Country	Production in 1,000 tons	Utilization (1,000 tons)												
		Cement (addition or replacement of hydraulic binder)	Cement kilns	Roads	Cellular concrete	Compacted concrete			Lightweight aggregate	Bricks	Filler on construction sites	Miscellaneous	Total	Percent of production used
						Blocks	Prepared concrete	Dams						
France	4,022	832	124	726	-	102	-	-	-	1	286	53	2,124	53
Greece	250	-	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	391	-	-	57	-	10	-	-	-	77	95	9	248	63
Poland	4,990	15	-	25	525	175	-	-	-	-	200	-	940	19
Rumania	1,500	22	-	-	33	-	-	-	-	-	-	23	78	5
United Kingdom	9,440	18	-	1,647	-	938	55	-	65	31	1,013	12	3,779	40
U.S.S.R.	30,000	-	-	-	-	-	-	-	-	-	-	-	-	-
United States	20,000+	-	-	-	-	-	-	-	-	-	-	-	2,400	¹ 12
West Germany	10,400	5	-	550	40	850	800	-	-	-	450	35	2,730	26

¹ Does not include that used within the company.



FIGURE 2. - Estimated Fly-Ash Production in U.S. - 1967

F-022-Utilization of Phosphate Slimes-International Minerals
& Chemical Corp., EPA Project 14050 EPV

The study used slimes to produce lightweight concrete and other ceramic products. The major problem is drying the slimes. The second is that the slimes are located in Florida and shipping the dried material as a filler would be uneconomical. The third problem is that materials cannot be produced on an economic basis with conventional products.

78

F-023-Solid Waste as Fuel for Power Plants-Horner and
Shifrin Inc. PB 220-316

This is primarily directed at developing waste as fuel for a furnace. The attached Table presents a breakdown of waste. This may be a possible source for filler.

TABLE NO. 2

COMPOSITION RANGES OF REFUSE
WEIGHT PER CENT, AS RECEIVED

	<u>Oceanside</u> (4 lots)	<u>Philadelphia</u>
Paper	33.72 - 53.33	54.4
Textiles (Rags)	2.24 - 3.97	2.6
Rubber, Plastics, Leather	2.45 - 8.82	1.7
Garbage	7.23 - 16.70	5.0
Wood	1.22 - 6.58	2.4
Glass and Ceramics	7.13 - 11.87	9.1
Metal	7.23 - 10.60	8.4
Ash and Dirt	-----	16.4
Grass, Leaves and Dirt	0.26 - 33.33	----